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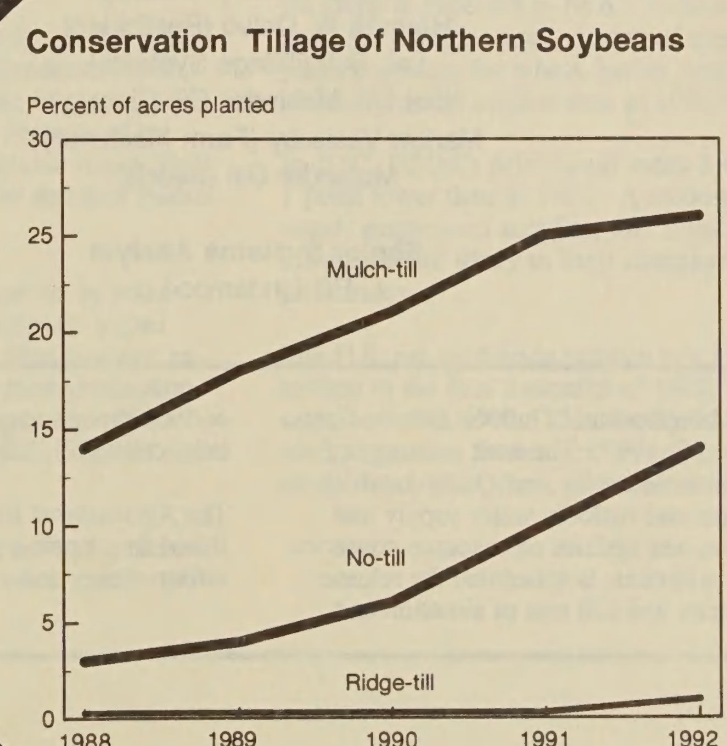

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Approved by the World Agricultural Outlook Board. Summary released February 12, 1993. The next summary of the *Agricultural Resources Situation and Outlook*, which will feature cropland use and outlook, water supply and soil moisture conditions, and updates on resource conservation and water quality programs, is scheduled for release May 13, 1993. Summaries and full text of situation and outlook reports may be accessed electronically. For details, call (202) 720-5505.

The *Agricultural Resources Situation and Outlook* is published four times a year. See back cover for subscription information.

Summary

Some Midwestern States more than doubled the use of conservation tillage on corn and soybean acreage between 1991 and 1992.

USDA surveys indicate that no-tillage and ridge-tillage systems were used on 14 percent of the 1992 corn and soybean acreage in the major producing states, up from 10 percent in 1991. Mulch tillage was used on 25 percent of the 1992 corn acreage. The seven northern soybean producing states reported that mulch tillage was used on 26 percent of the 1992 acreage, compared to only 8 percent in the Southern States.

Fertilizer use in 1992/93 is expected to decrease 4 percent from 1991/92, while some fertilizer prices will likely remain flat or increase slightly if production costs rise. Nitrogen use is forecast at 10.9 million nutrient tons, phosphate at 4.1 million, and potash at 4.8 million. Planted area of corn, the crop most fertilized by farmers, will likely decline due to the increase from 5 to 10 percent in USDA's acreage reduction program (ARP) for corn. The reduction in corn acreage is expected to be partially offset by an increase in wheat planted area because the wheat ARP decreased from 5 to 0 percent.

U.S. fertilizer exports in 1992/93 are forecast to increase slightly from a year earlier, assuming significant market participation by China and India. Increased use in developing countries has helped offset reduced consumption in Eastern Europe and the former USSR. World production is projected to decline.

Pesticide use on the 10 major field crops in 1993 is projected at 472 million pounds of active ingredients (a.i.), down 3 percent from 1992. Herbicide use is expected to drop about 14 million pounds, primarily because of reduced corn acreage. Insecticide and fungicide use is likely to remain stable, but variability in weather and pest infestations will influence final consumption.

U.S. farmers can expect 1993 energy prices to be somewhat above 1992 averages, the result of slightly higher prices for imported crude oil. For 1992, direct energy expenditures (about 4 percent of total cash farm-production expenses) are expected to be 3 to 4 percent above 1991. The rise is attributed to higher energy prices, coupled with little change in energy use.

Farm tractor sales in 1992 totaled 52,800 units, 9 percent below 1991. Combine sales were 7,700 units, compared to 9,700 units in 1991. However, both tractor and combine 1993 unit sales are forecast to be up 1 to 2 percent.

Several demand factors weigh in favor of an encouraging 1993 forecast for machinery purchases. Farm income in 1992 is forecast up from 1991, largely due to bumper grain crops. Because machinery purchases tend to lag behind farm income, the increase in farm income in 1992 should be a positive indicator for 1993 machinery sales. The value of farm equity is forecast to increase in 1992 and probably again in 1993. Interest rates are low, another positive indicator for increased farm machinery purchases in 1993. However, 1992/93 commodity prices for many major field crops are expected to be lower than in 1991/92.

U.S. farm machinery exports were estimated at $3.2 billion in 1992, up 6.3 percent from 1991. Farm machinery imports declined for the second consecutive year. Exports, as a percentage of U.S. shipments, have been increasing since 1989 and are forecast to reach 33 percent in 1993. Farm machinery exports have exceeded imports for the last 4 years. The 1993 outlook is for another increase in farm machinery exports to about $3.3 billion and a slight decrease in imports to about $1.8 billion, resulting in trade surplus of $1.5 billion.

For the 1992/93 crop year, total seed use for the eight major crops is expected to be 6.1 million tons, up 2 percent from the previous year because of expected gains in planted acreage for wheat, barley, and oats. Seed use was estimated at 5.9 million tons in 1991/92.

In 1992, USDA's prices-paid index for all seeds was 162, 1 point lower than in 1991. A modest increase in seed demand, ample seed supplies, and small commodity price movement are likely to limit changes in the 1993 seed-price index.

The U.S. net seed-trade balance fell 13 percent to $286 million in the first 9 months of 1992, compared with the same period in 1991. This decline largely reflects gains in corn, vegetable, flower, and forage seed imports and declines in soybean, corn, and other seed exports.

Fertilizer Use Expected Down in 1992/93

The acreage reduction program (ARP) for corn increased from 5 percent in 1992 to 10 percent in 1993, while the ARP for wheat decreased from 5 to 0 percent. As a result, fertilizer use could drop 4 percent in 1992/93; however, some fertilizer prices will likely remain flat or increase slightly if production costs rise.

Consumption

Plant nutrient use in the United States is forecast at 19.8 million nutrient tons during fertilizer year 1992/93 (July 1-June 30), down 4 percent from 1991/92. Nitrogen use is forecast at 10.9 million tons, phosphate at 4.1 million, and potash at 4.8 million. During 1991/92, farmers used 11.4 million tons of nitrogen, 4.2 million of phosphate, and 5.0 million of potash.

Fertilizer use in 1992/93 is expected to decrease from 1991/92. Planted area of corn, the major fertilizer-using crop, will likely decline due to the increase of the ARP for corn from 5 percent to 10 percent (table 1). The reduction in corn acreage is expected to be partially offset by an increase in wheat planted area because the ARP for wheat decreased from 5 percent in 1992 to 0 percent in 1993. For cotton and soybeans, acreage is expected to decline slightly. Gains in planted area are also expected for barley and oats, but a decrease is anticipated for sorghum. Rice acreage is expected to remain about the same.

Fertilizer application rates on corn, cotton, soybeans, and wheat are expected to remain near those of 1992. Application rates in 1992 for corn, soybeans, and wheat were a little less than the previous year, due to wet soil conditions in some areas that hampered spring fertilizer applications. Cotton application rates in 1992 were up somewhat from those of 1991. The lower 1991/92 application rates may also reflect recommendations from soil testing and farmers' concerns for the environment.

Table 1--Acreage assumptions for 1993 input-use forecast

Crop	1992 actual	1993 forecast
	Million planted acres	
Wheat	72.3	73.3 - 76.3
Feed grains	107.5	99.7 - 105.7
Corn	79.3	72.0 - 76.0
Other 1/	28.2	27.7 - 29.7
Soybeans	59.0	58.0 - 61.0
Cotton (all types)	13.6	12.6 - 13.6
Rice	3.0	2.8 - 3.2

1/ Sorghum, barley, and oats.

Despite modest decreases in demand projected for 1993, fertilizer prices will likely remain flat or increase slightly in 1993, if production costs rise.

Exports of fertilizer materials during 1992/93 are projected to rise slightly from a year earlier, due to reduced production in Eastern Europe and the former USSR, as well as from increased demand in developing countries. Overall, nitrogen exports will likely climb 1 percent (table 2). Phosphate exports should increase about 4 percent if diammonium phosphate shipments to Asia stay strong. Potash exports are expected to increase over last year by about 14 percent because of expected increased demand from South American countries.

Supplies

Domestic supplies of nitrogen fertilizer should be adequate to meet 1993 crop needs because the aggregate of inventories, production, and imports should exceed consumption. However, anticipation of decreased planted acres in the U.S. and reduced world production are expected to encourage exports. Reduced production in Central and Eastern Europe tightened supplies, and, in general, strengthened the U.S. market in the 1991/92 fertilizer year. The forecast is for decreased domestic production in anticipation of less planted acres and slightly reduced nitrogen imports.

Domestic phosphate and potash supplies will be ample because decreased or stable domestic production, supplemented by potash imports from Canada, will exceed domestic demand.

Transportation difficulties may trigger some regional shortages of fertilizer materials this spring. The U.S. rail system is still plagued by hopper car shortages during peak demand periods, which could trigger spot fertilizer shortages in some areas or higher prices if additional transportation costs are passed on to farmers.

Nitrogen production rates for July-September 1992 were up less than 1 percent and indicate that about 96 percent of U.S. anhydrous ammonia capacity was being used (9). Wet-process phosphoric acid facilities, capable of producing almost 12.6 million tons of product a year, operated at 98 percent of capacity through September. During the same period in 1991, anhydrous ammonia and wet-process phosphoric plants operated at about 96 and 99 percent of capacity, respectively.

Table 2--U.S. supply-demand balance for years ending June 30

Item	Nitrogen			Phosphate					
	1991	1992	1993 /1	1991	1992	1993 1/	1991	1992	1993
				Million nutrient tons					
Producers' beginning inventory	1.14	1.02	1.14	0.52	0.57	0.54	0.34	0.19	0.25
Production	14.01	14.47	14.23	3/ 12.06	3/12.43	12.28	1.83	1.92	1.86
Imports	2/ 3.42	2/ 3.59	3.55	0.05	0.07	0.07	4.61	5.24	4.69
Total available supply	4/ 18.56	4/19.09	18.92	12.62	13.06	12.89	6.79	7.34	6.80
Agricultural consumption	11.18	11.40	10.90	4.15	4.21	4.10	4.98	5.05	4.80
Exports	3.37	3.42	3.45	5/ 5.57	6.58	6.82	0.63	0.66	0.75
Total agricultural and export demand	14.55	14.82	14.35	5/ 9.72	10.79	10.92	5.61	5.71	5.55
Producers' ending inventory	1.02	1.14	1.23	0.57	0.54	0.61	0.19	0.25	0.26
Available for non-agricultural use	4/ 2.99	4/ 3.13	3.34	2.34	1.74	1.36	0.99	1.38	0.99

1/ Forecast. 2/ Anhydrous ammonia data is understated because imports from the former USSR are not available. 3/ Does not include phosphate rock. 4/ Significantly understated due to lack of import data for anhydrous ammonia.

Sources: (2, 3, 6, 7, 8).

U.S. potash facilities operated at 77 percent of capacity, producing 0.6 million tons through October 1992. Canadian facilities operated at 59 percent, producing 2.6 million tons. A year earlier, potash plants in the United States and Canada operated at 81 and 52 percent of capacity, respectively.

Nitrogen production is projected to decrease less than 2 percent in 1992/93 from the previous year. U.S. nitrogen imports are expected to decrease about 1 percent, due to decreased domestic demand. Shipments will continue to come from Canada, the former USSR, and Trinidad-Tobago, with Canada being the major U.S. supplier (1). During 1991/92, anhydrous ammonia, ammonium nitrate, and ammonium sulfate production decreased 1, 5, and 5 percent, respectively, to 17.7, 2.1, and 2.3 million tons (table 3). Increased production of other nitrogen materials ranged from 3 percent for urea to 8 percent for nitrogen solutions.

U.S. phosphate production is expected to decrease about 1 percent in 1992/93 in response to relatively steady, or slightly less, domestic demand. Continued strength is expected in the export market. Diammonium phosphate production, which accounts for the largest proportion of U.S. phosphate fertilizer production, rose 4 percent during 1991/92. Production of normal and enriched superphosphate and triple superphosphate rose 2 percent in 1991/92.

In 1992/93, domestic potash production will likely decrease by less than 3 percent as a result of reduced domestic demand and higher operating costs. U.S. potash imports are also expected to decrease modestly in response to less planted acres.

Farm Prices

Spring 1993 fertilizer prices will likely remain flat or increase slightly from a year earlier. Increased production costs could put upward pressure on prices. Higher transportation costs will also contribute to increased fertilizer prices.

Table 3--U.S. production of selected fertilizer materials for years ending June 30

Material	1991	1992 1/	Annual change
	---1,000 tons---		Percent
Nitrogenous fertilizers: 2/			
Anhydrous ammonia 3/	17,804	17,667	-1
Ammonium nitrate, solid	2,166	2,060	-5
Ammonium sulfate	2,380	2,261	-5
Urea 3/	8,089	8,313	3
Nitrogen solutions	3,047	3,290	8
Phosphate fertilizers: 4/			
Normal and enriched superphosphate	52	54	2
Triple superphosphate	918	938	2
Diammonium phosphate	6,793	7,032	4
Other ammonium phosphates and other phosphatic fertilizer materials	1,300	1,335	3
Total 5/	9,064	9,358	3
Wet-process phosphoric acid 6/	11,580	12,154	5
Muriate of potash: 7/			
United States	1,834	1,917	5
Canada	8,290	7,729	-7

1/ Preliminary. 2/ Total not listed because nitrogen solutions are in 1,000 tons of N, while other nitrogen products are in 1,000 tons of material. 3/ Includes material for nonfertilizer use. 4/ Reported in 1,000 tons P2O5. 5/ Totals may not add due to rounding. 6/ Includes merchant acid. 7/ Reported in 1,000 tons of K2O.

Sources: (2, 8).

Nitrogen prices will likely increase if production costs of anhydrous ammonia increase. The major production cost of anhydrous ammonia is its feedstock, such as natural gas, fuel oil, or refinery gas, and a modest increase in price is expected. The natural gas price increase is mostly due to disruptions caused by Hurricane Andrew and to sea-

Table 4--Average U.S. farm prices for selected fertilizer materials 1/

Year	Anhydrous ammonia (82%)	Urea (44-46%)	Triple superphosphate (44-46%)	Diammonium phosphate (18-46-0%)	Potash (60%)	Mixed fertilizer (6-24-24%)	Prices-paid index
	$/ton						1977=100
1986:							
April	225	174	190	224	111	179	125
October	174	159	182	205	107	173	116
1987:							
April	187	161	194	220	115	176	117
October	180	159	206	231	135	183	121
1988:							
April	208	183	222	251	157	208	132
October	191	188	221	246	157	208	134
1989:							
April	224	212	229	256	163	217	141
October	180	172	204	218	153	196	131
1990:							
April	199	184	201	219	155	198	130
October	191	199	205	228	150	201	132
1991:							
April	210	212	217	235	156	206	136
October	188	203	211	228	148	202	132
1992:							
April	208	198	206	224	150	200	132
October	189	199	194	204	145	190	128

1/ Based on a survey of fertilizer dealers conducted by the National Agricultural Statistics Service, USDA.

sonal adjustments. Spring 1993 phosphate prices could be a little less than in the fall of 1992, as excess supplies dampen prices. Spring potash prices should be about the same as in the fall of 1992.

Fertilizer prices paid by farmers decreased slightly (less than 1 percent) from October 1989 to April 1990 (table 4). Prices fell again in late spring of 1990 due to excess supplies. Demand and supply were more in balance just prior to the Persian Gulf crisis in August. October 1990 farm prices included the initial shock of the crisis and an increase of 1 to 2 percent from April 1990. Spring 1991 prices were about 3 percent higher than fall 1990. Fall 1991 fertilizer prices were about the same as a year earlier and 3 percent less than spring 1991. During the first 9 months of 1992, prices dropped about 3 percent from the previous year. The increase in natural gas prices during the last quarter of 1992 has put upward pressure on nitrogen prices, with the increase expected to carry into the spring of 1993.

U.S. Fertilizer Trade

Depending on the year, anhydrous ammonia accounts for 35-60 percent of total nitrogen material imports and a relatively constant 25 percent of total nitrogen material exports. During calendar year 1989 the Department of Commerce (DOC) ceased reporting quantity data for anhydrous ammonia trade. The DOC took this action in response to a disclosure petition filed by a fertilizer importer. Although data for 1990, 1991, and 1992 are now available, the quantity of U.S. fertilizer trade data will be understated because imports from the former USSR are not available.

Fertilizer import volume in 1991/92 increased about 12 percent from a year earlier, while prices and product mix caused value to increase only 3 percent (table 5). Imports totaled approximately 16.3 million tons (8.9 million nutrient tons), valued at $1.3 billion. Canada provided a substantial share of U.S. nitrogen imports and almost all potash imports. During July-November of fertilizer year 1992/93, fertilizer import volume decreased about 3 percent.

U.S. fertilizer exports totaled 24.3 million tons (10.7 million nutrient tons), about 3 percent more than the previous year (table 6). Asian countries provided the largest markets, followed by Canada, and Latin America. China and India received about 25 and 12 percent, respectively, of all U.S. fertilizer exports. South Korea, the Netherlands, Mexico, Japan, France, India, and Canada were the recipients of around 21, 8, 7, 14, 14, 11, and 6 percent, respectively, of phosphate rock exports.

During July-November 1992, exports decreased about 22 percent as purchases by India and China were less than those of July-November 1991 (table 6). Processed phosphate exports decreased about 20 percent, and phosphate rock exports went down 38 percent. Imports and exports of potassium chloride, the major source of potash, decreased 19 and 3 percent.

Nitrogen Trade

Imports of anhydrous ammonia, ammonium sulfates, and ammonium nitrates increased in 1991/92 by 13, 19, and 24 percent, while imports of aqua ammonia, nitrogen solu-

Table 5--U.S. imports of selected fertilizer materials

Material	Fertilizer year 1990/91	Fertilizer year 1991/92	July-November 1991	July-November 1992
	1,000 tons			
Nitrogen:				
Anhydrous ammonia 1/	2,650	2,983	1,119	1,251
Aqua ammonia	10	7	2	3
Urea	1,980	1,682	688	639
Ammonium nitrate	408	505	207	174
Ammonium sulfate	317	378	126	121
Sodium nitrate	156	162	54	51
Calcium nitrate	66	104	39	27
Nitrogen solutions	256	207	75	33
Other	72	78	25	31
Phosphate:				
Ammonium phosphates	4	28	3	2
Crude phosphates	553	1,154	259	708
Phosphoric acid 2/	1	2	1	1
Normal and triple superphosphate	1	0	*	*
Other	2	1	*	*
Total	561	1,185	263	711
Potash:				
Potassium chloride	7,451	8,481	3,466	2,809
Potassium sulfate	68	69	23	16
Potassium nitrate 3/	34	30	5	16
Other	353	201	77	61
Total	7,906	8,781	3,571	2,902
Mixed fertilizers	193	229	72	84
Total	14,575	16,301	6,241	6,027
	$ billion			
Total value 4/	1.25	1.29	0.48	0.47

* = Less than 500 tons.

1/ Does not include imports from the USSR, thus nitrogen imports and domestic supply are significantly understated. 2/ Includes all forms of phosphoric acid. 3/ Includes potassium sodium nitrate. 4/ Value by fertilizer material in appendix Table 1.

Source: (7).

Table 6--U.S. exports of selected fertilizer materials 1/

Material	Fertilizer year 1990/91	Fertilizer year 1991/92	July-November 1991	July-November 1992
	1,000 tons			
Nitrogen:				
Anhydrous ammonia	853	574	235	133
Aqua ammonia	0	0	0	0
Urea	1,050	1,163	468	351
Ammonium nitrate	26	53	18	16
Ammonium sulfate	994	877	345	405
Sodium nitrate	5	8	2	1
Nitrogen solutions	447	395	157	168
Other	39	48	15	19
Total	3,414	3,118	1,240	1,093
Processed phosphate:				
Normal superphosphate	45	45	11	11
Triple superphosphate	752	1,145	485	581
Diammonium phosphate	9,538	10,670	4,717	3,464
Monoammonium and other ammonium phosphates	749	1,118	401	248
Phosphoric acid--				
Wet-process	544	591	260	292
Super	107	208	27	138
Other	103	18	6	8
Total	11,838	13,795	5,907	4,742
Phosphate rock 2/	6,607	5,576	2,571	1,582
Potash:				
Potassium chloride	805	789	318	309
Potassium sulfate	237	295	95	123
Other	336	347	153	110
Total	1,378	1,431	566	542
Mixed fertilizers	282	380	110	132
Total	23,519	24,300	10,394	8,091

1/ Declared value of exports not reported after 1985. 2/ Effective January 1984, phosphate rock exports include a small tonnage of miscellaneous fertilizers.

Source: (6).

tions, and urea decreased 30, 19, and 15 percent. Urea imports decreased from 1.98 to 1.68 million tons and represented 28 percent of all nitrogen material imports during 1991/92 fertilizer year.

In 1991/92 Canada remained the major foreign supplier of nitrogen fertilizer, providing about 57 percent of U.S. import tonnage. On a value basis, Canada was the major source of U.S. anhydrous ammonia imports, earning over 35 percent of anhydrous ammonia import value. Canada also provided most of the imported urea, supplying about 78 percent of the 1.68 million tons of U.S. imports. Trinidad-Tobago and Mexico each shipped another 6 percent.

In 1991/92 the volume of all nitrogen material exports decreased from the previous year. World nitrogen consumption has declined because of the economic changes in Eastern Europe and the former USSR. Overall nitrogen exports went down about 9 percent. Anhydrous ammonia, nitrogen solutions, and ammonium sulfate exports went down 33, 12, and 12 percent.

However, urea exports increased 11 percent and made up 37 percent of the 3.1 million tons of nitrogen materials exported. Exports of ammonium nitrate and sodium nitrate also increased by 104 and 60 percent, but they are small-volume exports (table 6). Diammonium phosphate (18 percent nitrogen and 46 percent phosphate) accounted for over 56 percent of the 3.4 million nutrient tons of nitrogen exported and 75 percent of the processed phosphate.

Brazil was the largest customer for U.S. ammonium sulfate, purchasing 40 percent of the 0.9 million tons exported. China, Chile, and Canada purchased the most urea, importing 54, 11, and 17 percent. Belgium-Luxembourg and France were the largest purchasers of nitrogen solutions, taking 13 and 85 percent.

Phosphate Trade

At 13.8 million tons, U.S. phosphate fertilizer exports in 1991/92 went up 17 percent from the previous year. China and India were the largest purchasers, accounting for 49 and 18 percent of the diammonium phosphate exports. Other important customers were Japan, Canada, Pakistan, Argentina, Colombia, and Venezuela. Although data on exports of superphosphoric acid to the former

USSR are not available, the Soviets buy large amounts of U.S. phosphate fertilizer.

Exports of most phosphate fertilizer materials increased—except for other phosphates. Exports of monoammonium and other ammonium phosphates, wet-process phosphoric acid, diammonium phosphates, triple superphosphate, and super phosphoric acid went up 49, 9, 12, 52, and 94 percent, respectively. Exports of normal superphosphates remained at their year-earlier level.

India purchased 35 percent of all U.S. super phosphoric acid exports. Australia received about 21 percent (241,000 tons) of concentrated superphosphates. China received 49 percent (5.2 million tons) of diammonium phosphate exports, and Canada imported 30 percent (332,000 tons) of monoammonium phosphate. South Korea purchased the most U.S. phosphate rock, accounting for 21 percent of all exports, while Mexico, the Netherlands, Japan, France, India, and Canada took 7, 8, 14, 7, 11, and 6 percent.

At 5.6 million tons, U.S. phosphate rock exports declined 16 percent in 1991/92, continuing a trend toward the shipping of processed phosphate fertilizer rather than rock. Phosphate rock of other exporting countries has a higher ore content than that of the United States.

Potash Trade

U.S. exports of potassium fertilizer materials increased about 4 percent in 1991/92. Approximately 1.4 million tons were shipped, with potassium chloride accounting for 55 percent of the total (table 6). Brazil and Mexico received 45 and 9 percent of the potassium chloride shipped. Potassium sulfate exports went up 24 percent, comprising 21 percent of potassium exports. China received 49 percent of the potassium sulfate exported.

U.S. potassium chloride imports increased about 14 percent in 1991/92 to 8.5 million tons (table 5). Potassium chloride accounted for almost all potash imports, with Canada providing 94 percent of the total, up from 92 percent the previous year. Israel, the former USSR, and Germany were the only other significant importers, supplying 2, 1, and 1 percent.

Fertilizer Use Estimates

In 1991/92, 47.5 million tons of fertilizer material were used in the United States and Puerto Rico, up less than 1 percent from the previous year (table 7). Use of plant nutrients of 20.7 million tons represented an increase of less than 1 percent from the previous year. Nitrogen use increased 1 percent to 11.4 million tons, while phosphate and potash use remained about the same at 4.2 and 5.0 million tons.

Changes in regional consumption varied (table 8). Plant nutrient use fell as much as 5 percent in the Southern Plains. In the Delta States, it rose as much as 14 percent due to changes in crop mix, planted acreage and a return to historical application rates for nitrogen, phosphate, and potash.

Table 7--U.S. fertilizer consumption 1/

Year ending June 30 2/	Total fertilizer materials	Primary nutrient use				
		N	P2O5	K2O	Total	(1977=100) 3/
	Million tons					Percent
1977	51.6	10.6	5.6	5.8	22.1	100
1980	52.8	11.4	5.4	6.2	23.1	104
1981	54.0	11.9	5.4	6.3	23.7	107
1982	48.7	11.0	4.8	5.6	21.4	97
1983	41.8	9.1	4.1	4.8	18.1	82
1984	50.1	11.1	4.9	5.8	21.8	99
1985	49.1	11.5	4.7	5.6	21.7	98
1986	44.1	10.4	4.2	5.1	19.7	89
1987	43.0	10.2	4.0	4.8	19.1	86
1988	44.5	10.5	4.1	5.0	19.6	89
1989	44.9	10.6	4.1	4.8	19.6	89
1990	47.7	11.1	4.3	5.2	20.6	93
1991	47.3	11.2	4.2	5.0	20.5	93
1992	47.5	11.4	4.2	5.0	20.7	94

1/ Includes Puerto Rico. Detailed State data shown in appendix Table 2. 2/ Fertilizer use estimates for 1977-84 are based on USDA data; those for 1985-92 are TVA estimates. 3/ Totals may not add due to rounding.

Source: (3).

Table 8--Regional plant nutrient consumption for year ending June 30 1/

Region	1991	1992	Annual change
	1,000 tons		Percent
Northeast	749	803	7
Lake States	2,440	2,396	-2
Corn Belt	6,587	6,534	-1
Northern Plains	2,695	2,654	-2
Appalachia	1,584	1,711	8
Southeast	1,425	1,506	6
Delta States	992	1,134	14
Southern Plains	1,707	1,626	-5
Mountain	964	942	-2
Pacific 2/	1,313	1,316	0
U.S. total 3/	20,455	20,621	0.8

1/ Includes N, P2O5, and K2O. Totals may not add due to rounding. 2/ Includes Alaska and Hawaii. 3/ Excludes Puerto Rico. Detailed State data shown in appendix Table 2.

Source: (3).

Nitrogen use increased except in the Lake States, Corn Belt, Northern and Southern Plains States, and Mountain States, where it remained the same or decreased less than 3 percent (table 9).

Use of phosphate decreased in some regions and increased in others. The Delta States had the greatest increase (17 percent), while the Southern Plains showed the most reduction (14 percent). Phosphate application rates on cotton returned to more historical levels.

Potash use increased 2, 8, 8, 22, and 10 percent in the Northeast, Appalachia, Southeast, Delta States, and the Pacific regions. The Mountain region had the greatest decrease of 25 percent.

Table 9--Regional plant nutrient use for year ending June 30 1/

Region	1991	1992	Annual change
	---1,000 tons---		Percent
Nitrogen:			
Northeast	299	328	10
Lake States	1,128	1,119	-1
Corn Belt	3,280	3,279	-0
Northern Plains	1,978	1,954	-1
Appalachia	662	718	8
Southeast	627	655	4
Delta States	609	674	11
Southern Plains	1,223	1,192	-3
Mountain	628	619	-1
Pacific 2/	838	849	1
U.S. total 3/	11,273	11,385	1.0
Phosphate:			
Northeast	188	208	11
Lake States	479	468	-2
Corn Belt	1,262	1,269	1
Northern Plains	583	577	-1
Appalachia	384	409	7
Southeast	281	295	5
Delta States	154	180	17
Southern Plains	334	298	-14
Mountain	255	263	3
Pacific 2/	274	247	-10
U.S. total 3/	4,195	4,204	0.2
Potash:			
Northeast	262	267	2
Lake States	832	809	-3
Corn Belt	2,044	1,987	-3
Northern Plains	134	123	-9
Appalachia	539	584	8
Southeast	517	556	8
Delta States	229	280	22
Southern Plains	150	146	-2
Mountain	80	60	-25
Pacific 2/	200	220	10
U.S. total 3/	4,988	5,031	0.9

1/ Totals may not add due to rounding. 2/ Includes Alaska and Hawaii. 3/ Excludes Puerto Rico. Detailed State data shown in appendix Table 2.

Source: (3).

The proportion of fertilizers applied as single nutrient materials remained constant, constituting 60 percent of U.S. fertilizer use in 1991/92 (table 10). Farmers continued to use more concentrated materials to meet plant nutrient needs.

Corn for Grain

Fertilizer was applied to 97 percent of the corn acres in 1991/92 (table 11). The proportion of acres fertilized with nitrogen and phosphate remained unchanged, while the proportion fertilized with potash decreased. Application rates of nitrogen, phosphate, and potash decreased slightly from a year earlier to 127, 57, and 79 pounds per acre. Since 1985, nitrogen application rates have fallen about 13 pounds per acre, with the decline most dramatic between 1985 and 1986.

Table 10--Average annual U.S. fertilizer use 1/

Year ending June 30 4/	Multiple nutrient 2/ Quantity	Multiple nutrient 2/ Share of total	Single nutrient 3/ Quantity	Single nutrient 3/ Share of total
	Million tons	Percent	Million tons	Percent
1980	23.3	44	29.5	56
1981	23.5	44	30.5	56
1982	20.9	43	27.8	57
1983	18.4	44	23.5	56
1984	21.2	42	28.9	58
1985	20.6	44	26.7	56
1986	17.8	42	24.7	58
1987	17.1	42	24.1	58
1988	17.6	41	25.1	59
1989	17.6	41	25.2	59
1990	18.4	41	26.9	59
1991	17.8	40	26.8	60
1992	18.0	40	27.2	60

1/ Includes Puerto Rico. 2/ Fertilizer materials that contain more than one primary nutrient. 3/ Materials that contain only one nutrient. 4/ Fertilizer use estimates for 1980-84 are based on USDA data; those for 1985-92 are TVA estimates.

Source: (3).

Cotton

The proportion of acres receiving some fertilizer in 1991/92 decreased to 80 percent, down from 81 in 1990/91. The proportion of acres receiving nitrogen and phosphate decreased to 80 and 48 percent, respectively, and increased to 37 for potash. Application rates for nitrogen decreased to 88 from 91 and increased for potash to 57 from 48.

Rice

Fertilizer was applied on 98 percent of the rice acreage in 1991/92. The proportion of acres treated with the various nutrients ranged from 98 percent for nitrogen to 34 percent for phosphate. The application rate for nitrogen, at 134 pounds per acre, was up 7 pounds from a year earlier. Rates for phosphate decreased 2 pound per acre to 44 pounds, while potash rates increased to 50 pounds.

Soybeans

Some fertilizer was applied to 29 percent of soybean acres planted in 1991/92. This was up from 28 percent the previous year, as the proportion of acres fertilized declined for nitrogen and increased for phosphate and potash. Application rates for nitrogen, phosphate, and potash decreased from the preceding year. Application rates were the highest for potash (76 pounds per acre), followed by phosphate (47 pounds), and nitrogen (22 pounds). There were some differences in application rates between the northern and southern regions, with the North applying less nitrogen and phosphate per acre and more potash.

Wheat

The share of wheat acres fertilized increased from 80 percent in 1990/91 to 84 percent in 1991/92. The proportion of acres treated with nitrogen increased to 83 percent, and the proportion treated with phosphate increased to 56 per-

Table 11--Fertilizer use on selected U.S. field crops 1/

Crop, year	Acres receiving: Any fertilizer	N	P205	K20	Application rates: N	P205	K20
	--------Percent--------				----Pounds/acre----		
Corn for grain:							
1985	98	97	86	79	140	60	84
1986	96	95	84	76	132	61	80
1987	96	96	83	75	132	61	85
1988	97	97	87	78	137	63	85
1989	97	97	84	75	131	59	81
1990	97	97	85	77	132	60	84
1991	97	97	82	73	128	60	81
1992	97	97	82	72	127	57	79
Cotton:							
1985	76	76	50	34	80	46	52
1986	80	80	50	39	77	44	50
1987	76	76	47	33	82	44	45
1988	80	80	54	32	78	42	39
1989	79	79	54	32	84	43	40
1990	80	79	49	31	86	44	47
1991	81	81	52	34	91	47	48
1992	80	80	48	37	88	48	57
Rice:							
1988	99	99	46	36	127	47	50
1989	99	99	46	33	125	45	45
1990	98	97	36	37	114	45	49
1991	99	99	30	32	127	46	47
1992	98	98	34	37	134	44	50
Soybeans:							
1985	32	17	28	30	15	43	72
1986	33	18	29	31	15	43	71
1987	30	15	25	28	20	47	75
1988	32	16	26	31	22	48	79
1989	34	17	28	32	18	46	74
Northern area	30	14	23	28	16	48	77
Southern area	44	24	42	44	21	43	67
1990	31	17	24	29	24	47	81
Northern area	27	14	20	25	22	47	87
Southern area	41	26	38	39	28	47	70
1991	28	16	22	25	25	48	77
Northern area	26	14	19	22	24	49	80
Southern area	37	21	33	35	28	45	70
1992	29	15	23	26	22	47	76
Northern area	27	13	19	23	20	46	76
Southern area	39	22	36	37	27	49	74
All wheat:							
1985	77	77	48	16	60	35	36
1986	79	79	48	19	60	36	44
1987	80	80	50	15	62	35	43
1988	83	83	53	18	64	37	52
1989	81	81	53	18	62	37	46
1990	79	79	52	19	59	36	44
1991	80	80	54	20	62	36	43
1992	84	83	56	18	63	34	39

1/ Detailed data for selected States by crop shown in appendix tables 3-7.

cent. Potash-treated acres decreased to 18 percent. Phosphate and potash application rates decreased to 34 and 39 pounds per acre, while the rate for nitrogen went up to 63 pounds.

World Fertilizer Review and Prospects

World plant nutrient production and use decreased in 1989/90 and is likely to decrease in 1990/91 and 1991/92. Fertilizer production and consumption rose significantly in developing market economies (Asia, Africa, and Latin America), but only slightly in developed market economies. However, changes in Central and Eastern Europe and the former USSR, the crisis in the Persian Gulf, and other world developments reduced production and consumption, resulting in lower overall estimates. There has also been a significant decline in fertilizer consumption in Western Europe due to policies to reduce crop surpluses, environmental protection measures, and the integration of the former German Democratic Republic.

World Supplies

Between 1988/89 and 1989/90, world plant nutrient supplies decreased more than 3 percent to 143.8 million metric tons (table 12). Nitrogen supplies decreased 1 percent to 79.9 million tons, and phosphate supplies went down 5 percent to 37.7. Potash supplies decreased 8 percent to 26.2 million metric tons. World supplies likely declined another 3 percent during fertilizer year 1990/91. Reduced production in Central and Eastern Europe and the former USSR has reduced world supplies in the short term. Pro-

Table 12--World plant-nutrient supply and consumption for years ending June 30

Plant nutrient	1990	1991	1992 1/
	Million metric tons		
Available supply: 2/			
Nitrogen	79.9	77.6	77.2
Phosphate	37.7	36.9	37.6
Potash	26.2	24.6	24.1
Total 3/	143.8	139.1	138.9
Consumption:			
Nitrogen	79.2	77.1	76.2
Phosphate	37.4	36.0	34.6
Potash	26.9	24.4	23.5
Total 3/	143.5	137.5	134.3

1/ Projected. 2/ Production less industrial uses and losses in transportation, storage, and handling.
3/ Totals may not add due to rounding.

Source: (4, 5).

duction will probably decline slightly in 1991/92 because the industrial restructuring in Eastern Europe and the former USSR is continuing.

Consumption

Between 1988/89 and 1989/90 world plant nutrient consumption decreased less than 2 percent from a year earlier to about 143.5 million metric tons (table 12). Nitrogen use dropped less than 1 percent, while phosphate and potash use fell less than 2 and 4 percent. Nitrogen, phosphate, and potash consumption decreased to about 79.2, 37.4, and 26.9 million metric tons. In 1990/91, world plant nutrient use went down an estimated 4 percent due to decreased demand in Central and Eastern Europe and the former USSR. Demand in the developing market economies of Latin America and Asia is still strong. World demand could drop another 3 percent in 1991/92 because of the aforementioned conditions in Europe and the former USSR.

World Trade Developments

Existing nitrogen trade patterns are expected to continue. Canada, Eastern Europe, and the former USSR will continue to supply nitrogen fertilizer to the United States, Western Europe, and Asia. Additional nitrogen fertilizer production in Canada and Trinidad-Tobago will compete for a share of the already crowded North American, West European, and Mediterranean markets. Surplus nitrogen from the Near East will probably move to Asian markets.

Phosphate production is expected to grow in most regions. Although U.S. consumption is stabilizing, world consumption will increase, tightening the supply-demand balance. Asia should have the most active trade, because countries in that region are expected to produce only a small share of the phosphate they need. The African and U.S. phosphate industries will compete for this growing market.

Canada, Germany, Israel, and the former USSR are the major potash exporters. Canadian exports are expected to outdistance those of other major exporters by further penetrating the large Indian and Chinese markets and continuing shipments to the United States.

World Fertilizer Prices

Intensified use of fertilizer in developing countries has temporarily helped to offset reduced consumption in Central and Eastern Europe and the former USSR. Further, projected world production also is expected to decline. World consumption dropped about 1.6 percent in 1989/90, while available supply decreased 3.2 percent. Both supply and demand is expected to decline in 1991/92 and 1992/93. World prices in 1992/93 will reflect the demand-supply situation with prices being close to the 1991/92 levels.

Global Projections to 1997

According to 1992 forecasts of the Food and Agriculture Organization/United Nations Industrial Development Organization/World Bank/Industry Working Group, world fertilizer consumption of nitrogen, phosphate, and potash is expected to grow 8, 8, and 9 percent during 1992-97, while supply potential is expected to increase by 10, 5, and 7 percent (table 13). Fertilizer production and use are projected to grow fastest in developing countries in South America and Asia, and the developing market and centrally planned economies of Asia.

Table 13--Projected 1992-97 change in world fertilizer supply and consumption 1/

World regions	Nitrogen	Phosphate	Potash
	Percent increase		
Supply potential:			
Africa	16	11	0
America:	4	3	12
North America	3	3	11
Central America	3	-1	0
South America	12	7	2/
Asia:	23	16	8
West Asia	84	31	5
South Asia	30	14	0
East Asia	11	12	2/
Europe:	4	-6	-10
East Europe	9	1	0
West Europe	1	-9	-10
Former USSR	-3	1	14
Oceania	0	0	0
Total	10	5	7
Consumption:			
Africa	29	22	20
America:	6	6	8
North America	0	-1	2
Central America	19	34	33
South America	31	17	23
Asia:	15	13	12
West Asia	19	21	27
South Asia	25	26	16
East Asia	10	7	5
Europe:	-4	4	7
East Europe	11	50	100
West Europe	-8	-5	-4
Former USSR	-4	-3	6
Oceania	28	30	8
Total	8	8	9

1/ Detailed data in appendix Table 8. 2/ Production scheduled.

Source: (4)

By 1997, consumption in Western Europe is expected to decline from 4 to 8 percent, depending on the nutrient. This is down from earlier projections of over-10-percent growth. The slower rate of growth in U.S. consumption assumes continuation of acreage set-aside programs. Stable demand in Western Europe will also slow growth in world fertilizer use and curb nitrogen and phosphate production rates. North American potash exports to South America are expected to rise, supporting growth in U.S. and Canadian potash production. Smaller potash production increases in Eastern Europe and the former USSR could reduce exports from those countries.

In the developing countries of Africa, Central and South America, and Asia, the supply potential for nitrogen, phosphate, and potash is expected to climb as much as 84 percent by 1997. Consumption could rise as much as 100 percent in Eastern Europe. The rapid rise in consumption can be attributed to the goal of many developing countries (India, China) to become self-sufficient in food and fertilizer production.

Nitrogen demand growth in Western Europe and the United States is uncertain. Nitrogen and phosphate production in the developed countries is expected to increase during the next 5 years, while potash production will decline slightly. Most of the nitrogen increase will come from greater Canadian production. Higher phosphate fertilizer production in the United States will depend heavily on phosphate export potential.

New and more efficient ammonia plants are scheduled to be completed during the next few years in Canada, Trinidad-Tobago, the United Kingdom, and Belgium. New urea plants are planned for Saudi Arabia, Indonesia, Bangladesh, India, Pakistan, Java, and China. Nitrogen production is expected to increase near natural gas reserves in Indonesia, India, Saudi Arabia, Mexico, and Trinidad-Tobago. Among centrally planned economies in Asia, greater nitrogen production capacity will be limited mainly to plants built in China.

This surplus of nitrogen production capacity will likely provide sufficient supplies until the year 1997. However, the world will then need more production capacity. Therefore, prices will have to increase to make it profitable to expand production to meet demand.

Africa, Asia, Oceania, South America, and Western Europe are projected to have nitrogen deficits through 1997. North and South America, Eastern Europe, the former USSR, and West Asia will have surpluses because countries like these, with plentiful natural gas resources, produce nitrogen fertilizer for export.

Phosphate production will center primarily in the United States, the former USSR, and Morocco during 1991-97. About 30 percent of the phosphoric acid supply capability will be located in the United States, 20 percent in the former USSR, and 10 percent in Morocco. Increased phosphate production in India, China, Mexico, Tunisia, and Brazil will also add to world supplies.

The developed countries and Africa are projected to have surpluses of phosphate fertilizer. The former USSR, Asia,

Table 14--Projected regional shares of world fertilizer-supply potential and demand for years ending June 30

World regions	Nitrogen		Phosphate		Potash	
	1992	1997	1992	1997	1992	1997
			Percent			
Supply potential:						
Africa	2.6	2.7	13.4	14.1	0.0	0.0
America:	20.6	19.4	31.1	30.4	37.8	39.8
North America	14.5	13.5	26.2	25.6	37.4	39.0
Central America	4.3	4.0	1.6	1.5	0.0	0.0
South America	1.9	1.9	3.3	3.3	0.4	0.8
Asia:	38.9	43.5	22.0	24.2	7.8	7.9
West Asia	38.9	6.4	3.7	4.6	7.6	7.5
South Asia	3.8	12.1	2.7	3.0	0.0	0.0
East Asia	10.3	24.9	15.6	16.6	0.1	0.3
Europe:	18.1	17.0	13.8	12.4	25.9	21.8
East Europe	6.4	6.3	4.9	4.7	0.0	0.0
West Europe	11.6	10.7	8.9	7.7	25.9	21.8
Former USSR	19.3	16.9	18.0	17.2	28.5	30.4
Oceania	0.5	0.5	1.7	1.7	0.0	0.0
Consumption:						
Africa	2.8	3.3	3.3	3.7	2.1	2.4
America:	19.8	19.4	18.8	18.5	29.3	29.2
North America	15.1	13.9	12.6	11.5	21.3	20.0
Central America	2.4	2.7	1.4	1.8	1.3	1.6
South America	2.3	2.8	4.8	5.2	6.7	7.6
Asia:	49.2	52.1	41.0	43.0	23.6	24.3
West Asia	3.4	3.8	4.7	5.3	0.6	0.7
South Asia	13.1	15.1	10.8	12.6	6.6	7.1
East Asia	32.7	33.2	25.4	25.1	16.4	16.5
Europe:	16.9	15.0	14.2	13.7	23.0	22.7
East Europe	3.5	3.6	2.4	3.3	2.6	4.7
West Europe	13.4	11.4	11.9	10.4	20.5	18.0
Former USSR	10.6	9.4	20.2	18.2	20.9	20.4
Oceania	0.7	0.8	2.4	2.9	1.1	1.1

Source: (4).

and Eastern Europe will be deficit areas, with Asia having the most acute shortage.

Worldwide, phosphate rock capacity will be more than adequate to meet demand, with the main surplus areas being North America and Africa. Jordan and Morocco are major phosphate producers and have large-capacity additions planned for the next 5 years. The former USSR and India are forecast to be the world's largest importers of phosphoric acid, accounting for an estimated 45 percent of world trade. China, Brazil, Mexico, and India will also remain significant importers of processed phosphates through the 1990's, because the excavation of new phosphate mines in those countries will take considerable time and their phosphate rock processing facilities have not been fully developed.

Potash supply capability should be adequate into the next decade. World potash production potential is expected to increase about 6 percent. The greatest surplus is forecast for North America, due to heightened Canadian production. Israel, Jordan, Brazil, Thailand, and China will add to worldwide capacity.

Europe and the former USSR will have major potash surpluses even though production has been reduced more than 1 million tons during the reunification of Germany. Reduced production is also anticipated in the former USSR during the next 2 years. Asia, Africa, and Central and South America are projected to be deficit areas.

Projected regional shares of world fertilizer supply and demand indicate a continued shift in production and use from the developed to the developing countries (table 14). The combined share of Europe and the former USSR in world production will remain relatively constant through 1997 at around 34 percent for nitrogen, 30 percent for phosphate, and 53 percent for potash. Consumption of each nutrient in these areas will also remain about the same (32 to 44 percent of the world total), or will be slightly reduced.

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Pesticides

Pesticide Use Down 3 Percent in 1993

Planted area for corn, a heavy pesticide user, is expected to decrease, more than offsetting the increase in small-grain acreage.

Consumption

Pesticide use on the major field crops in 1993 is projected at 472 million pounds of active ingredients (AI), down 3 percent from a year earlier (table 15). Planted area for corn is expected to decrease, but increase for wheat, barley, and oats. Area planted to other crops is expected to change little from 1992.

Herbicides account for 84 percent of total pesticide use, while insecticides make up 14 percent. The expected 13.8-million-pound decrease in herbicide use expected in 1993 is attributed to the projected decline in corn acreage. Corn accounts for 55 percent of herbicide use.

Insecticide use in 1993 is expected to decline slightly from 1992. Fungicide use on major field crops is expected to remain stable, with most being used in peanut production.

1992 Pesticide Use

Corn

Herbicides were used on 97 percent of the surveyed corn acreage in 1992 (table 16). Nebraska and South Dakota farmers treated the fewest acres for weed control, 92 percent.

Table 15--Projected pesticide use on major U.S. field crops, 1993

Crops 1/	Herbicides	Insecticides	Fungicides
	Million pounds (a.i.) 2/		
Row crops:			
Corn	220.1	27.2	0.07
Cotton	20.8	20.2	0.21
Grain sorghum	11.6	1.9	0.00
Peanuts	6.6	1.4	6.48
Soybeans	105.1	9.2	0.06
Tobacco	1.3	3.0	0.40
Total	365.5	62.9	7.22
Small grains:			
Barley and oats	4.4	0.1	0.00
Rice	12.7	0.5	0.07
Wheat	15.6	2.1	0.86
Total	32.6	2.7	0.93
1993 total	398.1	65.6	8.15
1992 total	411.9	67.0	8.12

1/ See Table 1 for crop acreage. 2/ Active ingredient.

In the 10 surveyed states, an average of 1.4 herbicide treatments were made to control weeds. A single herbicide treatment was used on 60 percent of the acreage and two treatments on 34 percent. Iowa, Minnesota, and South Dakota had the highest proportion of corn acreage treated twice with over 44 percent each.

Atrazine, used alone or in combination with other active ingredients, was the most commonly used herbicide. Atrazine + alachlor and atrazine + metolachlor were the most commonly used combination mixes, each accounting for 10 percent of the acre-treatments. These active ingredients control a large number of broadleaf and grass weeds and, when applied in combination, the control spectrum is broadened. Metolachlor was the most commonly used single material, with 10 percent of the acre-treatments, followed by alachlor and atrazine. Metolachlor and alachlor are from the same chemical family.

EPTC accounted for 9 percent of the acre-treatments in South Dakota. EPTC controls many annual grasses, especially wild proso millet, a major problem in the northern Corn Belt. It is also more biologically active at low soil temperatures than many other preplant herbicide materials.

Table 16--Selected herbicides used in corn production, 1992

Item	IL	IN	IA	MI	MN	MO	NE	OH	SD	WI	Area
1,000 acres planted 1/	11,200	6,100	13,400	2,700	7,200	2,450	8,300	3,800	3,800	3,900	62,850
1,000 acres treated with herbicides	11,047	6,001	13,154	2,622	7,118	2,379	7,665	3,705	3,482	3,658	60,831
Percent of acres treated:	99	98	98	97	99	97	92	98	92	94	97
With 1 treatment	61	78	48	73	49	79	66	75	44	68	60
With 2 treatments	35	20	47	22	45	17	25	22	44	24	34
With 3 or more	3	*	3	2	5	1	1	1	4	2	3
Average acre-treatments	1.42	1.22	1.56	1.25	1.57	1.19	1.31	1.26	1.56	1.31	1.41
1,000 acre-treatments	15,649	7,345	20,457	3,290	11,174	2,839	10,055	4,655	5,439	4,796	85,700
Acre-treatments by active ingredient: 2/						Percent					
Single materials--											
Alachlor	7	4	8	2	9	3	9	3	13	7	8
Atrazine	7	8	3	6	1	16	10	3	2	13	6
Bromoxynil	1	1	2	4	2	2	2	1	3	*	2
Cyanazine	2	*	2	3	2	4	2	2	2	4	2
Dicamba	2	2	5	4	14	1	2	7	20	4	6
EPTC	1	*	3	nr	4	nr	*	nr	9	1	2
Metolachlor	10	3	20	6	16	4	2	2	10	4	10
Nicosulfuron	2	2	2	1	7	1	2	*	3	3	2
2,4-D	6	3	3	3	5	3	6	4	7	1	5
Other	4	4	2	7	3	5	6	3	5	7	4
Combination mixes--											
2,4-D + dicamba	*	*	2	3	3	1	1	3	2	1	1
Atrazine + alachlor	10	25	6	15	2	15	21	16	1	8	10
Atrazine + bromoxynil	3	1	9	*	3	1	1	nr	3	nr	3
Atrazine + butylate	1	4	*	1	nr	3	1	3	1	nr	1
Atrazine + cyanazine	13	7	9	6	1	14	6	11	5	3	8
Atrazine + dicamba	8	4	7	2	5	1	2	5	7	3	5
Atrazine + metolachlor	13	20	5	18	2	22	16	14	nr	3	10
Atrazine + others	3	2	3	3	2	1	1	3	*	4	2
Other 2-way mixes	2	2	5	8	10	1	4	7	4	18	5
3-way and 4-way mixes	6	8	5	9	9	4	4	14	2	15	7
Total	100	100	100	100	100	100	100	100	100	100	100

nr - None reported. * - Less than 1 percent.

1/ Preliminary. 2/ Spot treatments not included.

Table 17--Selected insecticides used in corn production, 1992

Item	IL	IN	IA	MI	MN	MO	NE	OH	SD	WI	Area
1,000 acres planted 1/	11,200	6,100	13,400	2,700	7,200	2,450	8,300	3,800	3,800	3,900	62,850
1,000 acres treated with insecticides	2,869	1,651	4,065	616	789	603	4,845	656	470	1,360	17,924
Percent of acres treated:	26	27	30	23	11	25	58	17	12	35	29
With 1 treatment	25	27	30	23	11	25	44	17	12	35	26
With 2 treatments	1	nr	*	nr	nr	nr	12	nr	nr	nr	2
With 3 treatments	nr	nr	nr	nr	nr	nr	2	nr	nr	nr	*
Average acre-treatments	1.02	1.00	1.01	1.00	1.00	1.00	1.26	1.00	1.00	1.00	1.08
1,000 acre-treatments	2,915	1,651	4,109	616	789	603	6,116	656	470	1,360	19,285
Acre-treatments by active ingredient: 2/						Percent					
Carbofuran	4	7	4	1	5	5	7	3	3	6	5
Chlorpyrifos	34	31	30	56	34	38	22	29	11	26	29
Fonofos	16	12	8	4	17	nr	6	16	16	7	9
Permethrin	7	1	3	nr	nr	37	7	10	14	1	6
Phorate	4	7	2	6	19	nr	2	4	16	19	5
Tefluthrin	5	10	3	6	7	nr	10	1	nr	9	6
Terbufos	24	31	32	20	17	8	25	36	38	30	27
Other	7	1	18	7	nr	12	22	nr	3	1	13
Total	100	100	100	100	100	100	100	100	100	100	100

nr - None reported. * - Less than 1 percent.

1/ Preliminary. 2/ Spot treatments not included.

Much of the corn acreage in the upper Midwest is treated with dicamba, 2,4-D, or a combination of dicamba + 2,4-D. These materials are applied postemergence for broadleaf weed control.

Insecticides were used on 29 percent of the corn acreage in 1992 (table 17). Insecticide use was greatest in Nebraska, where 58 percent of the corn acreage was treated. In contrast, Minnesota and South Dakota farmers treated around 12 percent of their corn acreage and Ohio farmers, 17 percent. In Nebraska, corn rootworm larvae is frequently a problem because about two-thirds of the corn acreage is irrigated and a high proportion is planted to corn every year, allowing a buildup of the pest. In Minnesota, Ohio, and South Dakota, more corn acreage is rotated with other crops, including small grains, thus reducing corn rootworm problems.

Insecticides are generally applied at planting for corn rootworm larvae control. Insecticides are also used to control cutworms and European corn borers. Chlorpyrifos (29 percent) and terbufos (27 percent) were the most commonly used insecticides.

Soybeans

In 1992, 98 percent of the northern, and 95 percent of the southern, soybean acreage in the surveyed states was treated with herbicides (table 18 and 19). In the northern soybean region farmers applied 1.5 treatments per acre, compared with 1.7 treatments in the southern region.

In the northern region, Illinois, Iowa, and Minnesota had the highest number of treatments per acre, 1.6. Farmers in these states typically use a preemergence herbicide and follow it with a postemergence application, if additional weed problems arise. In the southern region, Georgia (1.4) and North Carolina (1.3) had the fewest treatments per acre. In these states, a large proportion of soybean acreage is double-cropped with winter wheat. Because soybeans are planted directly into the wheat stubble, less soil is disturbed and the leaf canopy is rapidly established, shading the ground and thereby inhibiting weed seed germination.

In the northern soybean region, imazethapyr and trifluralin, applied alone or in combination with other herbicides, were the most commonly used materials. Imazethapyr, registered in 1989, accounted for 18 percent of the herbicide acre-treatments in 1992, up from 9 percent in 1990. It controls a variety of broadleaf and grass weeds and may be applied preplant, preemergence, or postemergence. Its mode of action involves uptake by weed roots and/or foliage. Therefore, it controls existing weeds as well as germinating weeds. Trifluralin is applied preplant, soil-incorporated, and controls many broadleaf and grass weeds as they germinate.

Trifluralin, applied as a single active ingredient, was the most commonly used material in the southern region, accounting for 13 percent of the acre-treatments. Fourteen other active ingredients were applied alone, with none garnering more than 5 percent of the acre-treatments. Several combination mixes were used but none dominated.

Cotton

Herbicides were used on 89 percent of the cotton acreage in 1992, ranging from 100 percent in Mississippi to 76 percent in California (table 20). On average, cotton farmers applied 2.4 herbicide treatments per acre. Treatment frequency ranged from 3.6 to 5.3 in the Delta States to 1.3 in California. The severe weed pressure in the Delta is demonstrated by the large proportion of cotton acreage receiving three or more herbicide treatments per season. In

Table 18--Selected herbicides used in northern soybean production, 1992

Item	IL	IN	IA	MN	MO	NE	OH	Area
1,000 acres planted 1/	9,500	4,550	8,100	5,500	4,300	2,500	3,700	38,150
1,000 acres treated with herbicides	9,396	4,488	8,064	5,500	4,076	2,432	3,579	37,535
Percent of acres treated:	99	99	100	100	95	97	97	98
With 1 treatment	49	63	47	45	67	75	74	55
With 2 treatments	46	31	49	50	23	21	19	39
With 3 or more	4	5	4	5	5	1	4	4
Average acre-treatments	1.56	1.42	1.57	1.60	1.34	1.25	1.29	1.48
1,000 acre-treatments	14,691	6,375	12,662	8,810	5,481	3,045	4,610	55,674
Acre-treatments by active ingredient: 2/					Percent			
Single materials--								
Alachlor	*	2	1	1	2	6	5	1
Bentazon	7	2	3	3	2	2	1	4
Chlorimuron	3	3	3	nr	2	*	*	2
Clomazone	*	1	*	*	2	1	1	1
Ethalfluralin	1	*	2	1	nr	1	nr	1
Fluazifop-P-butyl	1	2	*	*	1	1	1	1
Glyphosate	2	5	3	1	4	1	4	3
Imazaquin	2	1	nr	nr	3	1	*	1
Imazethapyr	13	12	22	34	12	15	11	18
Metolachlor	2	3	1	1	*	2	3	2
Metribuzin	1	nr	1	1	1	*	2	1
Pendimethalin	9	3	6	2	2	5	3	5
Quizalofop-ethyl	1	*	1	1	1	nr	2	1
Sethoxydim	4	3	2	3	1	*	1	2
Trifluralin	8	3	21	29	10	14	2	14
Other	4	3	1	2	2	1	3	2
Combination mixes--								
Acifluorfen + bentazon	5	5	2	4	1	2	2	3
Fluazifop-P-butyl + imazethapyr	nr	nr	2	3	nr	nr	nr	1
Linuron + alachlor	nr	1	nr	1	*	*	2	*
Metribuzin + alachlor	nr	1	*	nr	nr	1	1	*
Metribuzin + chlorimuron	2	3	nr	nr	4	nr	3	2
Metribuzin + metolachlor	nr	1	[illegible]	nr	*	nr	2	*
Pendimethalin + imazaquin	5	8	nr	nr	14	2	9	4
Pendimethalin + imazethapyr	4	3	4	1	1	12	1	3
Trifluralin + alachlor	4	nr	2	2	2	*	nr	2
Trifluralin + clomazone	1	2	2	*	*	4	1	1
Trifluralin + imazaquin	1	2	nr	*	8	3	1	2
Trifluralin + metribuzin	*	*	1	*	nr	1	1	1
Thifensulfuron + chlorimuron	1	1	3	*	1	4	3	2
Other 2-way mixes	7	12	8	8	9	6	12	8
Chlorimuron + quizalofop + thifensulfuron	1	1	3	nr	1	1	1	1
Other combinations	10	19	4	1	12	13	26	10
Total	100	100	100	100	100	100	100	100

nr - None reported. * - Less than 1 percent.

1/ Preliminary. 2/ Spot treatments not included.

Texas and California, one or two herbicide treatments are the norm.

Of the herbicides applied as single ingredients, trifluralin was the most commonly used (24 percent). Fluometuron was used extensively in the Delta, and pendimethalin and prometryn in Texas and California, which indicate varying weed problems among regions. Combination mixes accounted for 28 percent of the acre-treatments, but no single combination accounted for more than 3 percent. MSMA was included in many of the combination mixes and was applied as a postemergence directed spray. With directed sprays, drop nozzles are used to place the herbicide material under the leaf canopy in the crop row.

Spring and Durum Wheat

In states producing spring and durum wheat, herbicide use ranged from a low of 74 percent in South Dakota to a high of 93 percent in North Dakota (table 21). Generally spring wheat growers apply herbicide once, but in Minnesota and North Dakota about 15 percent of the acreage received two treatments. In durum wheat production, 28 percent of the acreage in North Dakota received two herbicide treatments. The number of treatments needed for effective weed control decreases from east to west in the Northern Plains because weeds are more of a problem in higher rainfall areas.

The most commonly used herbicides on both crops were 2,4-D and MCPA, applied alone or in combination with dicamba. These materials are applied postemergence and control a wide range of broadleaf weeds. Trifluralin was

Table 19--Selected herbicides used in southern soybean production, 1992

Item	AR	GA	KY	LA	MS	NC	TN	Area
1,000 acres planted 1/	3,200	650	1,180	1,200	1,850	1,400	1,000	10,480
1,000 acres treated with herbicides	3,040	605	1,148	1,157	1,779	1,220	989	9,937
Percent of acres treated:	95	93	97	96	96	87	99	95
With 1 treatment	47	58	52	46	26	64	30	45
With 2 treatments	36	31	38	34	38	20	53	36
With 3 or more	12	4	7	16	32	3	16	14
Average acre-treatments	1.65	1.43	1.53	1.80	2.14	1.29	1.93	1.71
1,000 acre-treatments	5,026	864	1,760	2,081	3,810	1,572	1,909	17,022
Acre-treatments by active ingredient: 2/					Percent			
Single materials--								
Acifluorfen	3	4	1	1	4	1	2	3
Alachlor	*	10	1	1	nr	12	nr	2
Bentazon	1	1	1	1	1	1	1	1
Chlorimuron	4	13	4	5	2	5	3	4
Clomazone	1	nr	nr	6	2	*	*	1
Fluazifop-P-butyl	3	1	10	2	3	*	6	4
Fomesafen	2	nr	1	3	3	1	1	2
Glyphosate	2	3	10	4	6	2	6	4
Imazaquin	6	nr	3	2	6	1	8	5
Imazethapyr	nr	nr	5	nr	nr	3	5	1
Metolachlor	3	nr	5	3	1	6	3	3
Metribuzin	2	6	nr	7	4	2	1	3
Pendimethalin	6	12	1	2	6	3	5	5
Sethoxydim	3	3	1	6	4	1	4	3
Trifluralin	18	15	5	11	10	8	15	13
Other	6	7	5	14	8	4	6	7
Combination mixes--								
Acifluorfen + bentazon	12	2	4	4	5	1	7	7
Acifluorfen + imazaquin	3	2	1	3	6	nr	4	3
Alachlor + glyphosate	nr	nr	2	nr	nr	5	1	1
Fluazifop-P-butyl + fomesafen	1	nr	4	1	nr	1	1	1
Imazaquin + pendimethalin	4	4	3	2	6	18	1	5
Imazaquin + trifluralin	6	nr	5	1	2	1	1	3
Metribuzin + chlorimuron	*	4	2	1	1	*	2	1
Metribuzin + pendimethalin	*	7	nr	nr	*	nr	nr	1
Metribuzin + trifluralin	2	4	*	*	4	1	nr	2
Other 2-way mixes	7	2	10	11	8	9	8	8
Other combinations	4	3	15	11	7	9	9	8
Total	100	100	100	100	100	100	100	100

nr - None reported. * - Less than 1 percent.

1/ Preliminary. 2/ Spot treatments not included.

used extensively in durum wheat production for foxtail control.

Rice

In 1992, herbicides were used on 95 percent of the rice acreage in the two surveyed states--Arkansas and Louisiana (table 22). About one-third of the rice acreage received one herbicide treatment and 46 percent, two treatments. Propanil was the most commonly used herbicide in rice production, either alone or in combination with other materials. Fenoxoprop and molinate ranked second in importance. Propanil and molinate are used primarily to control barnyardgrass and a variety of other grass and broadleaf weeds. Fenoxaprop does not control broadleaf weeds or sedges.

Insecticides were used on 12 percent of the 1992 rice acreage (table 23). Carbofuran was the most commonly used insecticide in Louisiana to control the rice water weevil. Methyl parathion was used extensively in Arkansas to control rice stink bugs and grasshoppers.

Fungicides were used on 22 percent of the rice acreage (table 24). Sheath blight, caused by a soil-borne organism, poses the gravest disease problem in rice production. It kills the foliage, thereby reducing yields. Fungicides are only partially effective, slowing development of sheath blight but not controlling it.

Regulatory Issues

Methyl Bromide

The Environmental Protection Agency (EPA) has proposed listing methyl bromide as a Class I ozone-depleting substance. Under the Clean Air Act, the production, importing, and use of this fumigant in the United States would be phased out by the year 2000. Methyl bromide is used for soil, post-harvest, and quarantine fumigation to control a variety of pests. Soil fumigation uses that would be most affected include strawberries, tobacco, and fresh-market cucumbers, eggplants, peppers, and tomatoes. Approximately 64 million pounds of this material were used in the U. S. in 1990, more than 80 percent of which was for agri-

Table 20--Selected herbicides used in cotton production, 1992

Item	AR	LA	MS	TX	CA	Area
1,000 acres planted 1/	980	900	1,350	5,650	1,000	9,880
1,000 acres treated with herbicides	965	748	1,350	5,000	758	8,821
Percent of acres treated:	98	83	100	88	76	89
With 1 treatment	5	2	nr	57	58	38
With 2 treatments	15	6	6	27	11	20
With 3 treatments	24	13	28	4	7	11
With 4 treatments	31	8	22	nr	nr	7
With 5 treatments	17	13	24	nr	nr	6
With 6 or more	6	41	20	nr	nr	7
Average acre-treatments	3.61	5.28	4.39	1.41	1.33	2.43
1,000 acre-treatments	3,486	3,947	5,927	7,068	1,011	21,439
Acre-treatments by active ingredient: 2/						
Single materials--						
Cyanazine	8	8	6	*	8	5
Diuron	2	4	2	3	nr	3
DSMA	3	2	*	nr	nr	1
Fluazifop-P-butyl	2	5	2	1	2	2
Fluometuron	18	12	12	2	nr	9
Glyphosate	1	2	2	1	9	2
Methazole	1	4	1	nr	nr	1
MSMA	3	7	4	2	1	4
Norflurazon	3	6	3	nr	nr	2
Pendimethalin	3	3	2	10	22	6
Prometryn	3	5	2	15	8	7
Trifluralin	8	5	6	55	45	24
Other	1	10	3	5	3	5
Combination mixes--						
MSMA + cyanazine	6	2	7	*	nr	4
MSMA + fluometuron	5	3	6	nr	nr	3
MSMA + methazole	3	2	1	nr	nr	1
MSMA + prometryn	4	4	7	nr	nr	3
Norflurazon + fluometuron	4	3	5	nr	nr	3
Norflurazon + pendimethalin	2	1	3	nr	nr	1
Trifluralin + norflurazon	6	1	4	nr	nr	2
Trifluralin + prometryn	nr	nr	nr	1	3	1
Other 2-way mixes	10	10	15	5	nr	8
3-way mixes	3	1	5	*	nr	2
Total	100	100	100	100	100	100

nr - None reported. * - Less than 1 percent.

1/ Preliminary. 2/ Spot treatments not included.

cultural purposes. Soil fumigation accounted for 44-49 million pounds.

A USDA study estimated that economic losses in the U.S. would exceed $1 billion, without methyl bromide use, because alternative controls are either less cost-effective or unavailable. The registration of the most effective alternative soil fumigant for many crops, Vorlex, has been voluntarily canceled by the registrant to avoid reregistration costs, creating additional crop-production losses if methyl bromide is phased out. Additionally, imports of foreign-produced commodities and exports of U.S.-produced commodities would be constrained or prevented because alternatives are either not effective or economical enough to control the spread of exotic pests.

Methyl bromide is also subject to the Montreal Protocol, a treaty concerned with protecting the ozone layer. Under agreements reached in November 1992, the production and use of methyl bromide would be frozen at 1991 levels. So, U.S. agricultural producers would be subject to more stringent restrictions than producers in other countries.

Reduced-Risk Pesticides Program

The EPA is working on the establishment of incentives for the development, registration, and use of reduced risk pesticides. Currently, the EPA is preparing a Pesticide Regulation Notice to provide guidance to registrants for identifying new active ingredients that may be eligible for special treatment. In the longer run, EPA plans to (1) develop criteria for identifying lower risk pesticides, (2) streamline the registration process, including the possibility of exempting some materials recognized to be of low risk from the

Table 21--Selected herbicides used in spring and durum wheat production, 1992

Item	Spring wheat					Durum
	MN	MT	ND	SD	Area	ND
1,000 acres planted 1/	2,800	2,650	9,200	2,700	17,350	2,200
1,000 acres treated with herbicides	2,503	2,112	8,566	1,987	15,168	2,056
Percent of acres treated:	89	80	93	74	87	93
With 1 treatment	68	71	79	64	73	62
With 2 treatments	18	9	14	8	13	28
With 3 or more	3	nr	nr	2	1	3
Average acre-treatments	1.27	1.11	1.15	1.15	1.16	1.37
1,000 acre-treatments	3,182	2,343	9,834	2,292	17,651	2,813
Acre-treatments by active ingredient: 2/						
Single materials--						
2,4-D	11	13	21	22	18	17
Dicamba	1	5	nr	13	3	2
Diclofop-methyl	7	nr	1	nr	2	4
Imazamethabenz	nr	nr	1	nr	*	nr
MCPA	[illegible]	nr	11	7	[illegible]	12
Metsulfuron	nr	nr	1	nr	0	1
Triallate	5	nr	3	nr	3	2
Tribenuron	nr	nr	2	4	1	nr
Trifluralin	3	nr	4	nr	3	21
Other	5	5	1	4	3	nr
Combination mixes--						
2,4-D + clopyralid	nr	nr	1	nr	*	nr
2,4-D + dicamba	4	51	10	22	16	12
2,4-D + metsulfuron	nr	13	2	7	4	1
2,4-D + tribenuron	nr	nr	2	nr	1	3
MCPA + bromoxynil	23	nr	2	4	6	nr
MCPA + dicamba	4	3	9	7	7	13
MCPA + tribenuron	nr	nr	3	nr	2	2
Thifensulfuron + tribenuron	nr	nr	2	4	1	1
Triallate + trifluralin	nr	3	1	nr	1	4
Other 2-way mixes	7	3	6	nr	5	3
2,4-D + thifensulfuron + tribenuron	4	nr	4	2	3	1
2.4-D + Fenoxaprop-ethyl + MCPA	11	nr	2	nr	3	nr
MCPA + thifensulfuron + tribenuron	4	nr	2	nr	2	1
Other combinations	4	3	10	2	7	nr
Total	100	100	100	100	100	100

nr - None reported. * - Less than 1 percent.

1/ Preliminary. 2/ Spot treatments not included.

Federal Insecticide, Fungicide, and Rodenticide Act's registration requirements, (3) improve the informational content of pesticide labels and promote educational efforts, and (4) consider legislative proposals to extend exclusive use or patent-term protection to qualifying pesticides.

Worker Protection Standards

The EPA is implementing standards to protect employees on farms, and in forests, nurseries, and greenhouses from occupational exposure to agricultural pesticides. An important result will be changes in pesticide labels, including statements requiring pesticide users to comply with the standards, changes in restricted-entry levels, and/or changes in personal protective equipment. EPA estimates that 8,000 product labels will have to be altered.

EPA will use a variety of strategies to notify employers of agricultural workers about how to comply with the new standards. The standards require training of agricultural workers and pesticide handlers so that they understand and use the protective measures. EPA will develop training materials, conduct workshops for people who train workers and users, and establish a mechanism to verify which workers and handlers have received training. EPA plans to offer training to state, territorial, and tribal enforcement inspectors who will determine compliance, initiate enforcement, and help instruct agricultural employers, workers, and handlers on complying with the standards.

Table 22--Selected herbicides used in rice production, 1992

Item	AR	LA	Area
1,000 acres planted 1/	1,350	600	1,950
1,000 acres treated with herbicides	1,326	568	1,894
Percent of acres treated:	98	95	97
With 1 treatment	30	43	34
With 2 treatments	48	40	46
With 3 or more	20	12	17
Average acre-treatments	1.96	1.73	1.89
1,000 acre-treatments	2,600	985	3,585
Acre-treatments by active ingredient: 2/			
Single materials--			
2,4-D	4	7	5
Acifluorfen	2	2	2
Bentazon	1	3	1
Fenoxaprop-ethyl	7	14	9
Glyphosate	2	2	2
Molinate	8	21	11
Pendimethalin	1	nr	*
Propanil	37	20	32
Thiobencarb	3	2	3
Other	8	8	8
Combination mixes--			
Propanil + bromoxynil	1	1	1
Propanil + molinate	10	12	10
Propanil + pendimethalin	2	1	1
Propanil + thiobencarb	8	2	6
Other	6	8	7
Total	100	100	100

nr = None reported. * = Less than 1 percent.

1/ Preliminary. 2/ Spot treatments not included.

Table 23--Selected insecticides used in rice production, 1992

Item	AR	LA	Area
1,000 acres planted 1/	1,350	600	1,950
1,000 acres treated with insecticides	35	191	227
Percent of acres treated:	3	32	12
With 1 treatment	3	31	11
With 2 treatments	nr	1	*
Average acre-treatments	1.00	1.02	1.02
1,000 acre-treatments	35	196	231
Acre-treatments by active ingredient: 2/			
Single materials--			
Carbofuran	nr	85	72
Methyl parathion	69	15	23
Other	31	nr	5
Total	100	100	100

nr = None reported. * = Less than 1 percent.

1/ Preliminary. 2/ Spot treatments not included.

Table 24--Selected fungicides used in rice production, 1992

Item	AR	LA	Area
1,000 acres planted 1/	1,350	600	1,950
1,000 acres treated with fungicides	291	129	420
Percent of acres treated:	22	22	22
With 1 treatment	15	22	17
With 2 treatments	7	nr	5
Average acre-treatments	1.35	1.00	1.24
1,000 acre-treatments	391	129	520
Acre-treatments by active ingredient: 2/			
Single materials--			
Benomyl	72	67	71
Iprodione	15	13	14
Propiconazole	13	20	15
Total	100	100	100

nr = None reported.

1/ Preliminary. 2/ Spot treatments not included.

Corn and Soybean Production in 1992 Show Large Increases in Use of Conservation Tillage

Surveys indicate that no-tillage and ridge-tillage systems were used on 14 percent of the 1992 corn and soybean acreage in the major producing states, up from 10 percent in 1991. Mulch tillage was used on 25 percent of the 1992 corn acreage. The seven northern soybean states reported that mulch tillage was being used on 26 percent of the acreage, compared to only 8 percent of the 1992 acreage in the southern states.

Tillage operations as well as the amount of previous-crop residue on the soil surface after planting are important indicators of soil erosion potential. The conservation compliance provisions of the 1985 Food Security Act (FSA) require farmers to implement conservation plans on highly erodible land (HEL) by 1995 or become ineligible for farm program benefits. To meet these requirements on HEL, farmers must make a change in residue management (change crop rotation or use a different tillage system), add a cropping practice (such as contouring), and/or install permanent structures (such as terraces). The USDA has developed conservation plans for 140 million acres of highly erodible U.S. cropland. These plans include 105 million acres of residue management.

In terms of controlling water erosion, a conservation tillage system is defined as one that leaves 30 percent or more of the soil surface covered with previous-crop residue after planting. If less than 30-percent residue is left, the system is called conventional tillage.

Because the various tillage systems leave significantly different amounts of residue, the type of system used directly affects erosion potential and water quality. In general, conventional tillage systems without the moldboard plow leave less than one-half as much residue after planting as mulch-till systems. Of the acreage planted to major crops, currently 12 percent or less is tilled with a moldboard plow. The highest residue conservation tillage system, no-tillage, is used on 14 percent or less, depending on the crop. Most of the acreage is cropped with conventional tillage without the moldboard plow.

The tillage system employed influences the types and intensities of other input use. Labor hours spent in tilling the soil are determined by the number of times the farmer goes over the field, as well as implement size and tractor speed. Labor and fuel are normally reduced with tillage systems that require fewer trips over the field. In 1992, conventional tillage without a moldboard plow required an average of 2.7 passes over a field for corn and 5.9 for cotton. The number of hours per acre averaged 0.3 and 0.7, respectively. These numbers have decreased slightly over the past 5 years.

Tillage system designations were determined from the estimates of residue remaining after planting and the use of specific implements. To obtain the residue estimate, the percentage of residue remaining from the previous crop was estimated, and then reduced by the residue-incorporation rate of each tillage and planting implement used. For this report, the percentage of residue was assumed to be evenly distributed over the soil surface.

Corn

Tillage systems used in 1988 to 1992 corn production in the 10 major producing states indicate a trend toward the use of conservation tillage systems (table 25). In the surveyed states, a moldboard plow was used on 12 percent of 1992 corn acres, down from 20 percent in 1988. No-till systems were used on 12 percent of the corn acreage, a steady increase from 5 percent in 1989.

Ridge-till systems increased enough to be a significant factor, mainly in Nebraska and Minnesota. A corresponding increase is indicated in the average percentage of soil surface covered with residue. At the same time, decreases are reported in the number of hours per acre and the number of times over the field for tillage operations.

Missouri, Nebraska, and Ohio had the highest proportion of acres under no-till, likely reflecting implementation of conservation plans which must be fully implemented by the end of 1994 (appendix table 9). Corn acreage in Ohio had the highest proportion of acres under no-till (23 percent). Ohio has traditionally had a high proportion of no-till acreage because of the emphasis placed on such systems by its agricultural agencies. Nebraska had the highest average residue level, due to the prevalence of non-moldboard-plow tillage systems and extensive continuous corn production, much of which was irrigated. Nebraska and Ohio have consistently been among the highest users of no-till in corn production. No-till and ridge-till acreage is rapidly increasing in Iowa, Illinois, and Missouri. Iowa went from 6 percent no-till and ridge-till in 1991 to 12 percent in 1992. Illinois went from 12 percent to 18 percent, while Missouri increased from 9 to 19 percent over the same period, .

Mulch-till also increased 5 to 12 percent between 1991 and 1992 in Minnesota, Nebraska (irrigated), Illinois, Indiana, and South Dakota (appendix table 9).

These changes stem from increased awareness of conservation tillage benefits and the upcoming deadlines with respect to conservation compliance.

Wisconsin had the highest use of the moldboard plow—40 percent—to accommodate the corn/alfalfa rotations needed to support dairy farming. This was down from 64 percent in 1989. In Nebraska, the moldboard plow was used on less than 3 percent of the corn acres. Nebraska does not have a preponderance of wet/heavy soils which require fall plowing. Furthermore, it has a more serious wind erosion problem than the other major corn producing States.

Table 25--Tillage systems used in corn production, 1988 - 1992

Category	1988	1989	1990	1991	1992
Planted acres (1,000) 1/	53,200	57,900	58,800	60,350	62,850
			Percent of acres 2/		
Tillage system:					
Conv/w mbd plow 3/	20	19	17	15	12
Conv/wo mbd plow4/	20	59	57	55	49
Mulch-till 5/	14	17	18	20	25
Ridge-till 6/	*	*	*	*	2
No-till 7/	7	5	[illegible]	10	12
Residue remaining after planting:		Percent of soil surface covered			
Conv/w mbd plow	2	2	2	2	2
Conv/wo mbd plow	16	16	16	17	17
Mulch-till	38	38	38	38	38
Ridge-till	*	*	*	*	45
No-till	60	64	64	65	65
Average	19	19	22	24	27
			Number		
Hours per acre:					
Conv/w mbd plow	.8	.7	.7	.8	.6
Conv/wo mbd plow	.4	.4	.4	.4	.4
Mulch-till	.3	.3	.3	.3	.3
Ridge-till	*	*	*	*	.2
No-till	.1	.2	.2	.2	.1
Average	.5	.5	.4	.4	.3
Times over field:					
Conv/w mbd plow	4.0	4.1	3.8	3.9	3.6
Conv/wo mbd plow	3.5	3.5	3.4	3.4	3.1
Mulch-till	2.6	2.7	2.6	2.6	2.4
Ridge-till	*	*	*	*	1.5
No-till	1.0	1.3	1.1	1.2	1.1
Average	3.3	3.4	3.1	3.1	2.7

* Included in no-till for these years.

1/ Preliminary. 2/ May not add to 100 due to rounding. 3/ Conventional tillage with moldboard plow--any tillage system that includes the use of a moldboard plow and has less than 30 percent residue remaining after planting. 4/ Conventional tillage without moldboard plow--any tillage system that has less than 30 percent remaining residue and does not use a moldboard plow. 5/ Mulch-tillage--system that has 30 percent or greater remaining residue after planting and is not a no-till system. 6/ Ridge-tillage--system with the rows planted on ridges. 7/ No-tillage--no residue-incorporating tillage operations performed prior to planting, allows passes of nontillage implements, such as stalk choppers.

Soybeans

Soybean production also indicates a trend toward conservation tillage systems (tables 26 and 27). The 14 major soybean producing states are divided into the northern and southern areas. The northern area has steadily increased usage of no-till systems from 3 percent of the acreage in 1988 to 14 percent in 1992. At the same time, mulch-till has increased from 14 to 26 percent and use of the moldboard plow has dropped from 28 to 12 percent. The southern area has increased usage of no-till systems from 7 percent of the acreage in 1988 to 14 percent in 1992. During the same period, mulch-till has increased from 5 to 8 percent, while conventional tillage without the plow has decreased.

In the northern area, Indiana (24 percent) and Ohio (21 percent) were the greatest users of no-till systems in 1992 (appendix table 10). Iowa had the greatest proportional in-

Table 26--Tillage systems used in northern soybean production, 1988 - 1992

Category	1988	1989	1990	1991	1992
Planted acres (1,000) 1/	36,550	37,750	36,400	38,350	38,150
			Percent of acres 2/		
Tillage system:					
Conv/w mbd plow 3/	28	26	23	18	12
Conv/wo mbd plow 4/	55	51	51	48	47
Mulch-till 5/	14	18	21	25	26
Ridge-till 6/	*	*	*	*	1
No-till 7/	3	4	6	10	14
Residue remaining after planting:		Percent of soil surface covered			
Conv/w mbd plow	2	2	2	3	2
Conv/wo mbd plow	17	17	17	17	16
Mulch-till	39	37	38	39	40
Ridge-till	*	*	*	*	48
No-till	65	67	74	72	68
Average	17	19	19	25	28
			Number		
Hours per acre:					
Conv/w mbd plow	.7	.7	.6	.6	.6
Conv/wo mbd plow	.5	.5	.5	.5	.4
Mulch-till	.3	.4	.3	.4	.3
Ridge-till	*	*	*	*	.2
No-till	.1	.2	.2	.1	.1
Average	.5	.5	.5	.4	.4
Times over field:					
Conv/w mbd plow	4.2	4.3	4.2	4.3	3.9
Conv/wo mbd plow	4.0	4.1	4.1	4.1	3.7
Mulch-till	3.1	3.4	3.1	3.2	2.8
Ridge-till	*	*	*	*	1.6
No-till	1.0	1.2	1.1	1.1	1.0
Average	3.8	3.9	3.7	3.6	3.1

* Included in no-till for these years.

1/ Preliminary. 2/ May not add to 100 due to rounding. 3/ Conventional tillage with moldboard plow--any tillage system that includes the use of a moldboard plow and has less than 30 percent residue remaining after planting. 4/ Conventional tillage without moldboard plow--any tillage system that has less than 30 percent remaining residue and does not use a moldboard plow. 5/ Mulch-tillage--system that has 30 percent or greater remaining residue after planting and is not a no-till system. 6/ Ridge-tillage--system with the rows planted on ridges. 7/ No-tillage--no residue-incorporating tillage operations performed prior to planting, allows passes of nontillage implements, such as stalk choppers.

crease, from 4 percent in 1991 to 10 percent in 1992. In the southern area, Kentucky reported 44-percent usage of no-till and Tennessee 34 percent in 1992, up from 39 percent and 18 percent in 1991 (appendix table 11). These states have long been recognized by conservationists, as leaders in the advocacy and adoption of no-till systems.

Soybean acreage produced with ridge-till systems increased in Nebraska, Iowa, and Minnesota to such an extent that it is now large enough to report separately in the northern area.

The northern area reported that 12 percent of its acres in 1992 were farmed with a moldboard plow, compared with only 3 percent in the southern area. This was down from 28 percent in 1988 for the northern area and no change for the southern area. In contrast, 76 percent of southern area acreage used conventional tillage without the moldboard plow, compared with 47 percent of the northern area.

Mulch tillage was more predominant in the northern than the southern area (26 versus 8 percent), while no-till acreage has increased in the northern area to equal that of the southern area. The reason for some of these differences may be found in the examination of rotation data. In the southern area, 50-90 percent of previous-crop residue consisted of soybeans or a fallow period (leaving fragile and limited residues). In the northern area, over 60 percent of the previous-crop residue was corn, which leaves a hardier and heavier residue.

Table 27--Tillage systems used in southern soybean production, 1988 - 1992

Category	1988	1989	1990	1991	1992
Planted acres (1,000) 1/	12,200	13,380	11,850	10,800	10,480
	Percent of acres 2/				
Tillage system:					
Conv/w mbd plow 3/	3	4	4	3	3
Conv/wo mbd plow 4/	85	82	78	80	76
Mulch-till 5/	5	5	7	6	8
No-till 6/	7	10	12	11	14
Residue remaining after planting:	Percent of soil surface covered				
Conv/w mbd plow	2	2	1	1	1
Conv/wo mbd plow	8	13	10	8	8
Mulch-till	40	42	40	43	42
No-till	72	72	65	72	63
Average	14	15	19	17	18
	Number				
Hours per acre:					
Conv/w mbd plow	1.1	.8	1.0	1.0	1.3
Conv/wo mbd plow	.5	.6	.5	.5	.5
Mulch-till	.4	.3	.3	.2	.3
No-till	.2	.1	.2	.1	.2
Average	.5	.5	.5	.5	.5
Times over field:					
Conv/w mbd plow	4.1	4.3	4.3	4.5	4.5
Conv/wo mbd plow	4.6	4.8	4.4	4.6	4.7
Mulch-till	2.8	2.5	2.5	2.4	2.4
No-till	1.0	1.0	1.0	1.0	1.0
Average	4.3	4.3	3.8	4.1	4.0

1/ Preliminary. 2/ May not add to 100 due to rounding. 3/ Conventional tillage with moldboard plow--any tillage system that includes the use of a moldboard plow and has less than 30 percent residue remaining after planting. 4/ Conventional tillage without moldboard plow--any tillage system that has less than 30 percent remaining residue and does not use a moldboard plow. 5/ Mulch-tillage--system that has 30 percent or greater remaining residue after planting and is not a no-till system. 6/ No-tillage--no residue-incorporating tillage operations performed prior to planting, allows passes of nontillage implements, such as stalk choppers.

The residue remaining under conventional tillage was higher in the northern area. The machine labor hours per acre averaged 0.6 in the northern area and 1.3 in the southern area for conventional tillage with the moldboard plow, and the southern area averaged one more pass over the field.

The implementation of conservation plans, developed in response to conservation compliance requirements, are contributing to the increased acreage using conservation tillage systems. Another factor may be adoption of cost-saving technology. "Early-adopters" of these conservation systems are now suggesting advantages other than merely erosion reduction. These include direct cost benefits, such as fuel and labor savings, lower machinery investment, no yield reductions, and long-term benefits, such as better soil structure and fertility. Machinery designed specifically for conservation tillage has also become more available.

Spring and Durum Wheat

The types of tillage systems used in the production of spring and durum wheat indicate some variation over time, with recent growth in the use of no-till systems (tables 28 and 29). This may be partly due to weather-soil relationships in the area producing these crops.

Much of the wheat grown in the Great Plains and the Western States is produced after a fallow period. Implement passes made during the fallow year were included in determining residue levels, hours per acre, and trips over the field. Normal fallow procedure in these states starts with chisel plowing and other noninversion tillage operations in the fall instead of a pass with the moldboard plow. For these states, therefore, the tables reflect more trips over the field under conventional tillage without the moldboard plow (appendix table 12). North Dakota durum wheat acreage also shows this pattern because much of the durum wheat is planted after a fallow period.

Minnesota indicated greater use of the moldboard plow in spring wheat tillage operations in 1992 (24 percent). This is because most spring wheat in Minnesota is produced on heavy clay soils in the Red River Valley.

Table 28--Tillage systems used in spring wheat production, 1988 - 1992

Category	1988	1989	1990 1/	1991	1992
Planted acres (1,000) 2/	9,780	16,580	15,800	13,500	17,350
	Percent of acres 3/				
Tillage system:					
Conv/w mbd plow 4/	16	9	12	7	8
Conv/wo mbd plow 5/	62	61	63	55	61
Mulch-till 6/	21	29	23	37	25
No-till 7/	1	1	3	3	6
Residue remaining after planting:	Percent of soil surface covered				
Conv/w mbd plow	2	2	2	3	3
Conv/wo mbd plow	12	16	16	15	15
Mulch-till	39	40	39	43	41
No-till	63	id	64	65	53
Average	17	22	21	24	23
	Number				
Hours per acre:					
Conv/w mbd plow	.5	.5	.5	.5	.4
Conv/wo mbd plow	.4	.4	.3	.3	.3
Mulch-till	.3	.2	.2	.2	.2
No-till	.1	id	.1	.1	.1
Average	.4	.3	.3	.3	.2
Times over field:					
Conv/w mbd plow	4.7	3.3	3.7	3.7	3.3
Conv/wo mbd plow	4.4	4.1	4.1	4.0	3.9
Mulch-till	3.1	2.8	2.7	2.5	2.4
No-till	1.0	id	1.0	1.0	1.1
Average	4.1	3.6	3.7	3.4	3.3

id - Insufficient data.

1/ Idaho not included after 1989. 2/ Preliminary. 3/ May not add to 100 due to rounding. 4/ Conventional tillage with moldboard plow--any tillage system that includes the use of a moldboard plow and has less than 30 percent residue remaining after planting. 5/ Conventional tillage without moldboard plow--any tillage system that has less than 30 percent remaining residue and does not use a moldboard plow. 6/ Mulch-tillage--system that has 30 percent or greater remaining residue after planting and is not a no-till system. 7/ No-tillage--no residue-incorporating tillage operations performed prior to planting, allows passes of nontillage implements, such as stalk choppers.

Table 29--Tillage systems used in durum wheat production, 1988 - 1992

Category	1988	1989	1990	1991	1992
Planted acres (1,000) 1/	2,500	3,000	3,100	3,000	2,200
	Percent of acres 2/				
Tillage system:					
Conv/w mbd plow 3/	5	4	4	5	7
Conv/wo mbd plow 4/	69	57	62	55	55
Mulch-till 5/	24	39	34	37	35
No-till 6/	2	1	id	3	3
Residue remaining after planting:	Percent of soil surface covered				
Conv/w mbd plow	3	2	3	4	3
Conv/wo mbd plow	14	16	17	18	16
Mulch-till	39	43	42	39	42
No-till	72	id	id	40	68
Average	21	21	25	26	26
	Number				
Hours per acre:					
Conv/w mbd plow	.3	.3	.3	.2	.3
Conv/wo mbd plow	.4	.4	.3	.3	.3
Mulch-till	.2	.2	.2	.2	.2
No-till	.1	id	id	.1	.1
Average	.3	.3	.3	.3	.3
Times over field:					
Conv/w mbd plow	3.0	4.2	2.6	2.7	3.2
Conv/wo mbd plow	5.2	5.0	4.5	4.4	4.5
Mulch-till	2.9	2.8	3.0	2.9	2.5
No-till	1.0	id	id	1.0	1.0
Average	4.5	4.1	3.9	3.7	3.6

id - Insufficient data.

1/ Preliminary. 2/ May not add to 100 due to rounding. 3/ Conventional tillage with moldboard plow--any tillage system that includes the use of a moldboard plow and has less than 30 percent residue remaining after planting. 4/ Conventional tillage without moldboard plow--any tillage system that has less than 30 percent remaining residue and does not use a moldboard plow. 5/ Mulch-tillage--system that has 30 percent or greater remaining residue after planting and is not a no-till system. 6/ No-tillage--no residue-incorporating tillage operations performed prior to planting, allows passes of nontillage implements, such as stalk choppers.

Cotton

Nearly all cotton is produced using conventional tillage methods in the six major cotton states (table 30). However, use of the moldboard plow has decreased to less than half of the 1988 level.

Use of the moldboard plow was minimal (one percent or less) in Arkansas, California, Louisiana, and Mississippi (appendix table 13). While the plow was used most extensively in Arizona (47 percent of the acreage) and Texas (18 percent), its use is also decreasing. Arizona, California, and parts of Texas have state "plow-down" laws requiring that the cotton plant be disposed of to eliminate the overwinter food source for bollworms and boll weevils. Some producers have misinterpreted these laws to mean that the previous crop must be plowed with a moldboard plow. California producers mainly use multiple passes with a heavy disk. In some areas of Texas, the moldboard plow is also used to bring up subsoil clay to cover the soil surface with clods which helps control wind erosion.

The large number of tillage trips across the field (averaging 5.9) leaves very little residue, even without use of the moldboard plow. Research is being conducted in a number of cotton producing states on the use of mulch-till and no-till systems and the use of cover crops.

Rice

Heavy spring rains in 1990 delayed tillage and planting operations in the South-Central States. This caused many farmers to reduce the number of tillage operations. This may account for some of the increase in conservation tillage systems reported in 1990 rice production (table 31).

Table 30--Tillage systems used in cotton production, 1988 - 1992

Category	1988	1989	1990	1991	1992
Planted acres (1,000) 1/	9,700	8,444	9,730	10,860	10,200
	Percent of acres 2/				
Tillage system:					
Conv/w mbd plow 3/	28	15	14	21	12
Conv/wo mbd plow 4/	72	84	84	76	88
Mulch-till 5/	id	id	1	1	id
No-till 6/	id	id	1	1	id
Residue remaining after planting:	Percent of soil surface covered				
Conv/w mbd plow	0	0	0	0	0
Conv/wo mbd plow	3	3	3	3	3
Mulch-till	id	id	51	51	id
No-till	id	id	63	54	id
Average	2	2	3	3	3
	Number				
Hours per acre:					
Conv/w mbd plow	.8	.9	.8	.8	.8
Conv/wo mbd plow	.7	.7	.7	.7	.7
Mulch-till	id	id	.3	.4	id
No-till	id	id	.1	.1	id
Average	.8	.8	.7	.7	.7
Times over field:					
Conv/w mbd plow	6.2	7.2	6.6	6.4	6.3
Conv/wo mbd plow	6.1	6.4	6.2	6.2	5.9
Mulch-till	id	id	2.8	2.8	id
No-till	id	id	1.0	1.0	id
Average	6.1	6.5	6.2	6.1	5.9

id - Insufficient data.

1/ Preliminary. 2/ May not add to 100 due to rounding. 3/ Conventional tillage with moldboard plow--any tillage system that includes the use of a moldboard plow and has less than 30 percent residue remaining after planting. 4/ Conventional tillage without moldboard plow--any tillage system that has less than 30 percent remaining residue and does not use a moldboard plow. 5/ Mulch-tillage--system that has 30 percent or greater remaining residue after planting and is not a no-till system. 6/ No-tillage--no residue-incorporating tillage operations performed prior to planting, allows passes of nontillage implements, such as stalk choppers.

Apparently, these systems worked and were retained in later years.

Most of the rice acreage in Arkansas and Louisiana is produced under conventional tillage without the moldboard plow (appendix table 14). Arkansas reported 4-percent mulch-till in 1992, compared to less-than-1-percent in 1989. Louisiana reported 5-percent mulch-till and 3-percent no-till. Erosion is not a problem in rice production because most rice is planted on flat, heavy-textured soils which are flooded. Rice seedbeds usually are nearly residue free, partly because residue is perceived to harbor the disease organism that causes stem rot at the water line.

Winter Wheat

Tillage practices reported in 1988 through 1992 for winter wheat production indicated a reduction in the use of the moldboard plow and an increase in conservation tillage (table 32). Detailed data for 1992 was presented in *Agricultural Resources: Inputs, Situation and Outlook*, AR-28, USDA, Economic Research Service, October 1992.

Table 31--Tillage systems used in rice production, 1988 - 1992

Category	1988	1989	1990 1/	1991	1992
Planted acres (1,000) 2/	2,130	2,085	1,800	1,880	1,950
	Percent of acres 3/				
Tillage system:					
Conv/w mbd plow 4/	2	1	1	nr	nr
Conv/wo mbd plow 5/	96	97	96	94	95
Mulch-till 6/	2	id	3	4	4
No-till 7/	id	id	1	2	1
Residue remaining after planting:	Percent of soil surface covered				
Conv/w mbd plow	0	0	id	nr	nr
Conv/wo mbd plow	2	3	4	4	3
Mulch-till	41	id	46	38	45
No-till	id	id	45	63	57
Average	4	4	13	7	5
	Number				
Hours per acre:					
Conv/w mbd plow	id	id	id	nr	nr
Conv/wo mbd plow	.7	.5	.5	.5	.5
Mulch-till	.3	id	.3	.3	.2
No-till	id	id	.1	.1	0.0
Average	.6	.5	.5	.5	.5
Times over field:					
Conv/w mbd plow	id	6.4	id	nr	nr
Conv/wo mbd plow	6.0	6.0	5.9	5.9	4.9
Mulch-till	3.5	id	2.7	3.1	2.5
No-till	id	id	1.0	1.0	0.2
Average	5.9	6.0	5.8	5.7	4.7

id - Insufficient data.

1/ California not included after 1989. 2/ Preliminary. 3/ May not add to 100 due to rounding. 4/ Conventional tillage with moldboard plow--any tillage system that includes the use of a moldboard plow and has less than 30 percent residue remaining after planting. 5/ Conventional tillage without moldboard plow--any tillage system that has less than 30 percent remaining residue and does not use a moldboard plow. 6/ Mulch-tillage--system that has 30 percent or greater remaining residue after planting and is not a no-till system. 7/ No-tillage--no residue-incorporating tillage operations performed prior to planting, allows passes of nontillage implements, such as stalk choppers.

Highly Erodible Land

Within the surveyed crops and states, most of the highly erodible land in 1992 was reported as corn and winter wheat acreage (table 33).

More than 65 percent of the 1990 surveyed cropland, designated as HEL in each of the surveyed states, utilized conventional tillage methods. The single exception was with southern soybeans (54 percent). In 1992, this figure decreased to 49 percent for corn, to 46 percent for northern soybeans, and to 42 percent for southern soybeans. This

Table 32--Tillage systems used in winter wheat production, 1988 - 1992

Category	1988	1989	1990	1991	1992
Planted acres (1,000) 1/	32,830	34,710	40,200	34,180	36,990
			Percent of acres 2/		
Tillage system:					
Conv/w mbd plow 3/	15	16	12	12	11
Conv/wo mbd plow 4/	67	68	69	72	68
Mulch-till 5/	16	15	17	13	18
No-till 6/	1	1	3	3	3
Residue remaining after planting:		Percent of soil surface covered			
Conv/w mbd plow	2	2	2	2	2
Conv/wo mbd plow	14	14	14	14	14
Mulch-till	38	35	38	38	38
No-till	61	66	53	57	58
Average	17	17	18	17	19
			Number		
Hours per acre:					
Conv/w mbd plow	.7	.7	.7	.7	.6
Conv/wo mbd plow	.5	.5	.5	.5	.5
Mulch-till	.4	.4	.3	.4	.4
No-till	.1	.1	.1	.1	.1
Average	.5	.5	.5	.5	.5
Times over field:					
Conv/w mbd plow	5.3	5.3	5.3	5.6	5.3
Conv/wo mbd plow	5.0	4.8	5.0	5.0	4.9
Mulch-till	4.5	4.1	4.0	4.2	4.2
No-till	1.0	1.0	1.0	1.0	1.0
Average	4.9	4.7	4.7	4.9	4.7

1/ Preliminary. 2/ May not add to 100 due to rounding. 3/ Conventional tillage with moldboard plow--any tillage system that includes the use of a moldboard plow and has less than 30 percent residue remaining after planting. 4/ Conventional tillage without moldboard plow--any tillage system that has less than 30 percent remaining residue and does not use a moldboard plow. 5/ Mulch-tillage--system that has 30 percent or greater remaining residue after planting and is not a no-till system. 6/ No-tillage--no residue-incorporating tillage operations performed prior to planting, allows passes of nontillage implements, such as stalk choppers.

trend should continue over the next few years, as USDA-approved conservation plans are implemented.

The combination of conventional tillage (especially with the moldboard plow) on highly erodible cropland, creates the potential for significant erosion. However, the highly erodible acres which are conventionally tilled should not be interpreted as acreage that may be out of compliance with the 1985 and 1990 farm bills.

Other factors also influence erosion rates and would directly relate to meeting conservation compliance requirements. The calculation of the erosion rate considers the entire length of a rotation, not just the current crop and its tillage system. The calculated rate is the average of the sum of the individual rates for each crop, tillage, and practice combination over the life of the rotation. The presence of other practices, such as contouring or terracing, would also reduce the erosion rate. The soil and its erodibility characteristics also have a large influence, as does weather.

For winter wheat production, if seeding and growing conditions are favorable and the fall-planted winter wheat gets a reasonable start, the growing wheat alone is probably enough to meet USDA erosion-rate restrictions during critical erosion periods. This is particularly true for the spring wind-erosion period in most western states. These acres might meet compliance requirements regardless of the tillage system used.

Table 33--Erodibility distribution of crop acreage and tillage systems, 1992

Category	Winter wheat 1/	Corn	Northern soybeans	Southern soybeans	Cotton	Spring wheat	Durum wheat	Rice
Planted acres (1,000) 2/	36,990	62,850	38,150	10,480	10,200	17,350	2,200	1,950
Highly erodible land (%)	31	20	17	11	20	17	8	5
Land not highly erodible (%)	65	75	78	78	69	80	90	78
Land not designated (%)	4	5	5	11	11	3	2	17
Highly erodible land:								
Planted acres (1,000) 2/	11,580	12,460	6,700	1,160	2,085	2,950	180	100
				Percent				
Tillage system:								
Conv/w mbd plow 3/	9	10	4	2	12	3	nr	nr
Conv/wo mbd plow 4/	64	39	42	40	88	66	90	100
Mulch-till 5/	23	30	31	6	nr	30	10	nr
Ridge-till 6/	*	2	id	id	nr	*	*	*
No-till 7/	4	20	23	52	nr	1	nr	nr
Land not highly erodible:								
Planted acres (1,000) 2/	23,990	46,880	29,680	8,170	7,030	13,960	1,970	1,515
				Percent				
Tillage system:								
Conv/w mbd plow 3/	12	12	15	3	7	9	8	nr
Conv/wo mbd plow 4/	70	52	48	81	92	59	50	95
Mulch-till 5/	15	24	26	8	id	24	39	4
Ridge-till 6/	*	2	1	id	nr	*	*	*
No-till 7/	3	10	12	8	nr	8	3	1
Land not designated								
Planted acres (1,000) 2/	1,420	3,510	1,770	1,150	1,085	440	50	335
					Percent			
Tillage system:								
Conv/w mbd plow 3/	8	26	8	4	38	12	nr	nr
Conv/wo mbd plow 4/	79	42	57	73	62	88	100	95
Mulch-till 5/	11	18	18	6	nr	nr	nr	5
Ridge-till 6/	*	1	nr	nr	nr	*	*	*
No-till 7/	2	13	17	17	nr	nr	nr	nr

id = Insufficient data. nr = None reported. * = System not used.

1/ Harvested acres for winter wheat only. 2/ Preliminary. 3/ Conventional tillage with moldboard plow--any tillage system that includes the use of a moldboard plow and has less than 30 percent residue remaining after planting. 4/ Conventional tillage without moldboard plow--any tillage system that has less than 30 percent remaining residue and does not use a moldboard plow. 5/ Mulch-tillage--system that has 30 percent or greater remaining residue after planting and is not a no-till system. 6/ Ridge-tillage--system with the rows planted on ridges. 7/ No-tillage--no residue-incorporating tillage operations performed prior to planting; allows passes of nontillage implements, such as stalk choppers.

Little Change Foreseen for Energy Prices and Consumption

The price of energy to farmers is expected to change little in 1993, while energy consumption should remain about the same as in recent years.

U.S. farmers can expect 1993 energy prices to be somewhat above 1992 averages due to slightly higher prices for imported crude oil. For 1992, direct energy expenditures (about 4 percent of total cash farm production expenses) are expected to be 3 to 4 percent above the preceding year. The rise is attributed to higher energy prices coupled with little change in energy use.

The World Crude Oil Price

The world crude oil price is affected by supply, demand, and other factors such as expectations of market participants. Each factor is subject to considerable uncertainty. For example, current uncertainties concerning oil supply involve oil exports from the former USSR and production from the Organization of Petroleum Exporting Countries (OPEC).

In the former USSR, the production and domestic consumption of crude oil are expected to decline. The volume of crude oil available for export will be determined by the rate of decline in consumption, relative to production, as well as by the need for foreign exchange in the emerging market economies of the new republics.

Two OPEC countries, Kuwait and Iraq, are in the process of restoring their pre-war production capacity and export facilities. Kuwait is expected to increase oil production and exports as capacity is restored. Iraqi production will be constrained as long as the United Nations embargo against exports remains in effect. Aggregate OPEC production depends on the willingness of other OPEC members to increase their production, if necessary, as exports from Kuwait, and possibly Iraq, remain below normal.

The important uncertainties affecting oil demand over the next year or so include the magnitude of economic growth in the United States, Japan, and Western Europe and the severity of winter weather. Steady economic recovery is expected in Organization for Economic Cooperation and Development (OECD) countries. In the short run, variations in weather could have a greater impact on demand than variations in economic activity.

Two other uncertainties affect the extent to which these supply and demand uncertainties influence crude oil prices: excess crude oil production capacity and stocks of crude oil. Excess capacity is expected to remain unchanged in 1993 as increases in OPEC production equal additions to production capacity. During the first quarter of 1993, the market economies are expected to have enough stocks readily available to meet petroleum demand for 30 days, based on anticipated demand. This is comparable to the same period in 1992.

Given these uncertainties, the world price of crude oil is forecast by the Department of Energy to increase 0 to 13 percent through the end of 1993, with the most probable increase being around 3 percent.

Domestic Petroleum Consumption and Production

The Department of Energy has analyzed the consumption and production of refined petroleum products in the United States, assuming an average world price of crude oil of $20 per barrel through 1993. With a higher world crude oil price and a sluggish, though rebounding, economy, U.S. petroleum demand is expected to increase. At a world price of $20 per barrel, the demand for all refined petroleum products in 1993 is expected to be 17.32 million barrels per day, a 1.6-percent increase from 1992 (table 34).

Table 34--U.S. petroleum consumption-supply balance

Item	1989	1990	1991	1992	Forecast 1993
	Million barrels/day				
Consumption:					
Motor gasoline	7.33	7.23	7.19	7.25	7.28
Distillate fuel	3.16	3.02	2.92	2.99	3.13
Residual fuel	1.37	1.23	1.16	1.11	1.12
Other petroleum 1/	5.47	5.51	5.45	5.69	5.79
Total	17.33	16.99	16.72	17.04	17.32
Supply:					
Production 2/	9.91	9.70	9.90	9.73	9.47
Net crude oil and petroleum imports (includes SPR) 3/	7.20	7.17	6.63	7.01	7.55
Net stock withdrawals	0.21	0.12	0.19	0.30	0.30
Total	17.32	16.99	16.72	17.04	17.32
	Percent				
Net imports as a share of total supply	41.57	42.20	39.65	41.14	43.59
	Percent change from previous year				
Consumption		-1.96	-1.59	1.91	1.64
Domestic production		-2.12	2.06	-1.72	-2.67
Imports		-0.42	-7.53	5.73	7.70

1/ Includes crude oil product supplied, natural gas liquid (NGL), other hydrocarbons and alcohol, and jet fuel. 2/ Includes domestic oil production, NGL, and other domestic processing gains (i.e., volumetric gain in refinery cracking and distillation process). 3/ Includes both crude oil and refined products. SPR denotes Strategic Petroleum Reserves.

Source: U.S. Department of Energy, Energy Information

On the supply side, the $20-per-barrel price will not reverse the rate of decline in domestic crude oil production in 1993. As a result of this, coupled with increased domestic consumption, net crude oil and petroleum imports are expected to increase 7.7 percent in 1993.

In the event of a $20-per-barrel world oil price, the U.S. price of crude oil is assumed to increase by $0.58 per barrel (1.4 cents per gallon) from the third quarter of 1992 to the fourth quarter of 1993. Most refined petroleum product prices would increase by about 1.5 cents per gallon during this period due to the higher crude oil price, indicating that the refiner margin would change little. The exceptions are gasoline and diesel fuel.

The gasoline price will be subject to additional increases during the first half of 1993 due to higher supply costs associated with manufacturing, storing, and transporting gasoline designed to meet Federal requirements for oxygenate content that took effect in November 1992. Although the supply of oxygenates appears to be adequate, the estimated price increase caused by implementation of these rules is about 3 to 5 cents per gallon in the affected regions. The diesel fuel price will be between 2 and 5 cents per gallon higher beginning in late-1993 due to federally mandated lower sulfur-content requirements. This requirement, however, should have little impact on diesel fuel prices for most of 1993.

At $20 per barrel, the consumption of most refined petroleum products is expected to increase slightly in 1993. In the transportation sector, continued slow economic growth and moderately higher prices for gasoline and diesel fuel are expected to dampen travel demand. Growth in motor-vehicle miles traveled is expected to be more than offset by the continued improvements in vehicle efficiency that reduce gasoline and diesel fuel use. Higher fuel costs are expected to result in higher airline ticket prices, which in turn are expected to keep the demand for commercial jet fuel weak in 1993.

The slightly higher energy prices are expected to have a minimal effect on domestic production of crude oil in 1993. In a $20-per-barrel oil price scenario, domestic crude oil output is projected to decline 260,000 barrels per day in 1993 from expected 1992 output.

At $20 per barrel, 1993 net imports of crude oil are anticipated to increase 540,000 barrels per day to 7.55 million barrels, compared to an increase of 380,000 barrels in 1992. The expected 1993 increase largely reflects lower import rates during the first three quarters of 1992, giving a lower base level of imports.

End-of-year 1993 crude oil inventories are projected to be 340 million barrels, almost unchanged from 1992. Refined petroleum product inventories, however, are expected to decrease slightly in 1993 due to their abnormal buildup in 1992.

Electricity Prices and Availability

The dominant fuel used to generate electricity in the United States, coal, is projected to remain at its 1992 price to electric utilities for 1993. This is the result of continued increases in productivity and available excess coal-production capacity which offset a fourth-quarter price rise due to a stock buildup. The relatively heavy stock buildup in the fourth quarter of 1992 put some upward pressure on prices. A prolonged strike (which is possible in early 1993) would have the potential of raising prices. Otherwise the price of coal should not change significantly in 1993.

Accordingly, the price of electricity will not change appreciably. The price of electricity, in addition to being a function of the price of fuel, is dependent on interest rates (affecting the cost of capital for expansion and maintenance) and labor rates. Both rates are expected to increase minimally or not at all in 1993.

The present generating capacity for electricity is more than adequate to meet expected needs through 1993. Increases in electricity generation in 1993 are expected to be primarily from coal. Coal generating capacity is expected to continue increasing (at about 0.2 percent per year), while growth in hydroelectric and nuclear sources is constrained. The decline in hydroelectric generation expected for 1993 is attributed to below-normal water conditions in several areas of the country. Recent heavy rains on the West Coast, however, may alleviate the situation.

Energy in the Farm Sector

The U.S. agricultural sector's energy supply and price expectations are a reflection of world crude oil market conditions. Current world oil supplies are adequate and are expected to remain so through 1993. Fuel prices in the farm sector decreased in 1992 from 1991, but are likely to stabilize for 1993 at, or slightly above, 1992 levels. Farmers can expect plentiful supplies of gasoline, diesel fuel, and liquefied petroleum (LP) gas this year.

Little shift is expected in the input mix (i.e., fuel choice) over the next year. If crude oil prices rise, however, farmers will likely substitute relatively less expensive energy (e.g., natural gas) for refined petroleum products where possible.

Farm Fuel Use

Agricultural consumption of refined petroleum products, such as diesel fuel, gasoline, and liquefied petroleum gas, declined steadily between 1981 and 1989 (table 35). Since then, aggregate energy consumption has remained relatively constant.

Although the number of acres planted influences energy use, so do weather and other factors. For example, switching from gasoline to diesel-powered engines, adopting conservation tillage practices, changing to larger, multifunction machines, and creating new methods of crop drying and irrigation contributed to the earlier decline. While no-

Table 35--Gallons of fuel purchased for on-farm use: 1981-1991 1/ 2/

Year	Gasoline	Diesel fuel	LP gas
	Billion gallons		
1981	2.9	3.2	1.0
1982	2.4	2.9	1.1
1983	2.3	3.0	0.9
1984	2.1	3.0	0.9
1985	1.9	2.9	0.9
1986	1.7	2.9	0.7
1987	1.5	2.9	0.6
1988	1.6	2.8	0.6
1989	1.3	2.5	0.7
1990	1.5	2.7	0.6
1991	1.4	2.8	0.6

1/ Excludes Alaska and Hawaii.
2/ Excludes fuel used for household and personal business.

Source: U.S. Department of Agriculture, National Agriculture Statistics Service, Farm Production Expenditures, 1981, 1982, 1983, 1984, 1985, 1986, 1987, 1988, 1989, 1990, and 1991 summaries.

till and mulch-till farming practices have not been widely adopted, they are as prevalent as conventional tillage practices in some parts of the United States.

With only a minimal variation in the total number of acres planted and harvested, a few significant changes in cropping practices, and somewhat higher average energy prices, 1991 farm consumption of gasoline, diesel fuel, and LP gas remained near their 1990 levels.

Energy Prices Were Mixed In 1991 and Fell in 1992

Crude oil prices (especially imported crude, because it is the marginal supply in most instances) heavily influence the prices farmers pay for refined petroleum products. Historically, each 1-percent increase in the U.S. price of imported crude oil has translated into about a 0.7-percent rise in the farm price of gasoline and diesel fuel. In 1991, average gasoline prices increased 1.7 percent and diesel fuel prices fell 8.4 percent from 1990 (table 36). For 1992, gasoline prices were 3.4 percent below their 1991 average, while diesel fuel prices fell 5.7 percent.

Energy Expenditures Down in 1991

In 1991 (the most recent period for which data are available), farm energy expenditures on gasoline, diesel fuel, LP gas, electricity, natural gas, and lubricants totaled $7.26 billion, down nearly 3 percent from a year earlier (table 37). This fall reflects a 4.6-percent decline in fuel and lubricant expenditures, a 5-percent decrease in electricity expenditures for non-irrigation purposes, and a 16.9-percent jump in expenditures on electricity for irrigation.

Total expenditures on electricity, however, fell by about 1 percent. Higher energy prices and crop yields, and a slight fall in the number of acres planted and harvested in 1991 from 1990, accounted for these reductions. For 1992, relatively higher energy prices during the planting season, together with little change in energy use, will likely result in a 1.9-percent rise in farm energy expenditures.

Table 36--Average U.S. farm fuel prices 1/

Year	Gasoline	Diesel fuel	LP gas
		$/gallon 2/	
1981	1.29	1.16	0.70
1982	1.23	1.11	0.71
1983	1.18	1.00	0.77
1984	1.16	1.00	0.76
1985	1.15	0.97	0.73
1986	0.89	0.71	0.67
1987	0.92	0.71	0.59
1988	0.93	0.73	0.59
1989	1.05	0.76	0.58
1990	1.17	0.94	0.83
1991	1.19	0.87	0.75
1992	1.15	0.82	0.72
Jan 1991	1.26	1.05	0.88
April 1991	1.16	0.82	0.72
July 1991	1.16	0.77	0.68
Oct 1991	1.16	0.85	0.73
Jan 1992	1.08	0.77	0.75
April 1992	1.11	0.79	0.71
July 1992	1.21	0.84	0.69
Oct 1992	1.19	0.86	0.73

1/ Based on surveys of farm supply dealers conducted by the National Agricultural Statistics Service, USDA.
2/ Bulk delivered. The gasoline and LP gas prices include federal, state, and local per gallon taxes. The diesel fuel price excludes states road taxes and the federal excise tax and includes states and local per gallon taxes where applicable.

Table 37--Farm energy expenditures

Item	1988	1989	1990	1991	Forecast 1992
			$ billion		
Fuels and lubricants:					
Gasoline	1.42	1.44	1.65	1.50	1.48
Diesel	2.12	2.12	2.42	2.34	2.40
LP gas	0.38	0.38	0.53	0.44	0.47
Other	0.53	0.51	0.57	0.65	0.65
Electricity:					
Excluding irrigation	2.17	1.69	1.65	1.57	1.61
For irrigation	0.48	0.64	0.65	0.76	0.78
Total	7.10	6.78	7.47	7.26	7.39
Percent change from preceding year		-4.51	10.18	-2.95	1.93

Source: U.S. Department of Agriculture, National Agriculture Statistics Service, Farm Production Expenditures, 1987, 1988, 1989, 1990, and 1991 summaries.

Farm Machinery Retail Sales Down, Exports Up

Less farm machinery was purchased in the United States last year than in 1991, even though farm income was up and interest rates were down.

Monthly tractor and combine purchases from September through November 1992, were above the same months in 1991. However, due to slow sales from February through July 1992, the yearly totals were lower than for 1991. Some recovery in sales is expected for 1993.

Unit Sales Off in 1992

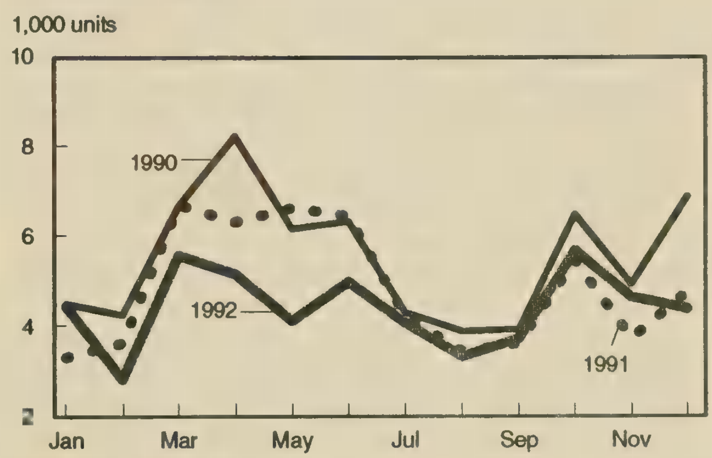
Tractor purchases showed a marked decrease in the first 8 months of 1992, but picked up from September through November (figure 1). The recovery was not enough to bring annual total sales above those for 1991 or 1990. Farm tractor sales for the year totaled 52,800 units, 9 percent below 1991 (table 38).

Sales of 40-100 horsepower tractors, totaled 34,500 units by the end of December, compared to 33,900 units at the end of 1991. The 40-100 horsepower class was the only class to show an increase in sales. Sales of 100-horsepower-and-over tractors, totaled 15,600 units in 1992, compared to 20,100 in December 1991. Four-wheel-drive sales, 2,700 units, were 35 percent below 1991.

Tractor unit sales are forecast to be up slightly in 1993. It is anticipated that demand factors favoring increased equipment purchases will outweigh those depressing demand. Farm income in 1992 is forecast up from 1991. Machinery purchases tend to lag behind farm income, a positive factor for 1993. The value of farm assets will probably continue to increase in 1993 and the debt-to-asset ratio should hold steady at about 14-15. Interest rates are the lowest they have been since 1962, another positive factor for increased purchases. Increases in the 40-to-100 and the over-100-horsepower categories are expected to provide the major increase in unit sales. Sales in the four-wheel-drive category are expected to remain stable at about 2,700 units.

Combine sales also fared better in the last 4 months of 1992, but due to slow sales in February through July, sales were down 21 percent from 1991 (figure 2). Sales in 1992 were 7,700 units, compared to 9,700 units in 1991. Combine sales are expected to recover slightly to about 7,800 units in 1993.

Figure 1
Farm Tractor Sales 1/



1/ Wheel tractors, 40 horsepower and above.
Source: Equipment Manufacturers Institute.

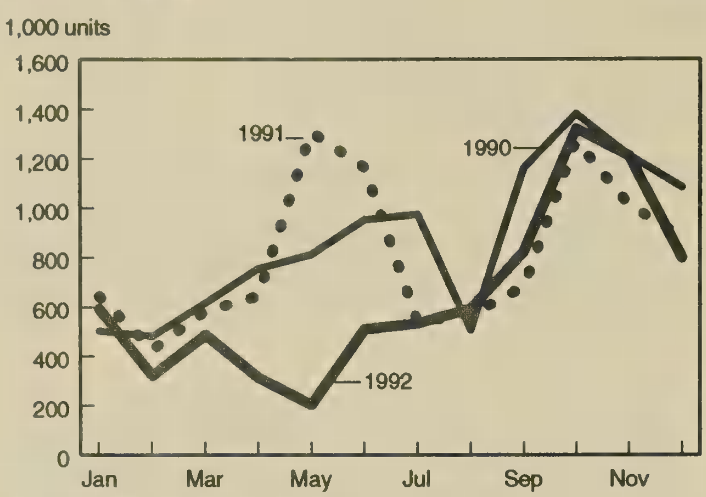
Table 38--Domestic farm machinery unit sales

Machinery category	1986	1987	1988	1989	1990	1991	1992P	1993F	Change 91-92	Change 92-93
	Units								Percent	
Tractors:										
Two-wheel-drive										
40-99 hp	30,800	30,700	33,100	35,000	38,400	33,900	34,500	35,200	2	2
100-139 hp 1/	5,100	5,100	4,300	5,200						
Over 139 hp 1/	9,100	10,800	11,800	15,400						
Total over 99 hp	14,300	15,900	16,100	20,600	22,800	20,100	15,600	15,700	-22	1
Four-wheel-drive	2,000	1,700	2,700	4,100	5,100	4,100	2,700	2,700	-35	0
All farm wheel tractors	47,100	48,400	51,700	59,700	66,300	58,100	52,800	53,200	-9	2
Grain and forage harvesting equipment:										
Self-propelled combines	7,700	7,200	6,000	9,100	10,400	9,700	7,700	7,800	-21	1
Forage harvesters 1/2/	2,200	2,300	2,400	2,800						
Haying equipment:										
Mower conditions 1/	10,900	11,200	11,000	13,200						

1/ Discontinued after 1989. 2/ Shear bar type.
P-preliminary. F-forecast.

Source: Equipment Manufacturers Institute (EMI).

Figure 2
Combine Sales



Source: Equipment Manufacturers Institute.

Unit tractor sales in 1992 were down 9 percent, instead of the 7-percent decline forecasted at the beginning of the year. However, the forecast was not as close as it seems to the actual decline. The largest unit sale class, 40-100 horsepower, had previously been forecast to decrease 11 percent, but sales were better than had been expected, up 2 percent by the end of the year. The smallest category, four-wheel-drive, was forecast to decrease 7 percent, but by the end of the year had fared much worse, decreasing 35 percent.

A look at the historic data show that when sales of all tractors decline, large (over 100 horsepower) tractor sales go down proportionately more than the smaller (40-100 horsepower) category. The reverse trend occurs when overall tractor sales are up. Proportionately more large tractors are sold when total sales increase. Thus, although the 1992 forecast for sales of all farm tractors was close to the actual year-end total, forecasts of individual classes varied greatly.

Farm Economy

Many economic factors in 1992 were favorable for increased investment in tractors and machinery and are expected to encourage increased capital investment in coming months. Nominal and real interest rates were the lowest they have been in several years. The value of farm assets were up. Farm debt, although slightly higher than last year, was still relatively low compared to the 1980's. Farm equity increased, which improved farmers' ability to borrow. In addition, farm income will likely be up in 1992 due to bumper grain crops. All of these factors being positive should encourage increased investment in machinery. Some factors are lagged; that is, the effect of higher incomes, for example, may not show up as increased machinery sales until 1993.

Why did 1992 farm machinery sales decrease when so many economic indicators were positive? There were probably several reasons. Apprehension about the general economy may have caused farmers to be cautious about making large capital investments. The economic slowdown affects everyone's buying decisions. Farmers are reluctant to invest in expensive capital items when they are not sure how long the economy will remain in a slowdown. Concern about the effects of drought in some parts of the country and anxiety about falling commodity prices and rising machinery prices are likely other factors. Also, late harvests in some areas of the country may have delayed capital investment purchases for some farm machinery.

Factors Affecting Sales

Demand for farm machinery is the result of a combination of many factors. Farm income, total value of farm assets, debt, interest rates, number of acres cropped, the age of machinery on farms, and many other factors play a part in shaping the demand for farm machinery.

Interest Rates

Lower interest rates usually have a positive effect on farm machinery purchases. The real (adjusted for inflation) prime rate was down to 3.6 percent in 1992 (table 39). The prime rate portends changes in the nominal machinery loan rate, which has also been down in recent years. Farm machinery and equipment loan rates were down to 9.3 percent (6.7 percent real rate). While the real rate reflects the actual cost of borrowing, the nominal rate probably has a more direct effect on machinery purchases because it is more obvious to farmers. Interest rates are negatively correlated with purchases of farm machinery. As interest rates fall, the total cost of machinery bought on credit decreases, facilitating increased purchases.

Cash Receipts, Expenses, and Income

Cash receipts were up in 1992 to $169 billion. Cash receipts are a combination of crop and livestock sales. Crop receipts for 1992 are forecast up at $84 billion. That will be an all-time high, provided the final numbers agree with the forecast. The 1992 crop receipts were up about $4 billion from the 1989 to 1991 average annual receipts that had held steady at $80 billion per year. Cash receipts were dampened somewhat, however, by a decrease in livestock receipts from $86.7 to $86 billion from 1991 to 1992.

Total expenses were nearly unchanged from 1990 to 1992, at about $145 billion per year. Decreases in total interest expenses were balanced by increases in other production expenses, such as pesticides. Machine hire and custom work were also up slightly from 1990 to 1992.

Income is the net difference that remains after farm expenses are subtracted from cash receipts. Net cash income is gross cash receipts, minus cash expenses. Net farm income includes inventory adjustments and non-money income, such as the value of home consumption of farm products and an imputed rental value on operator dwellings. Net farm income is forecast at $51 billion in 1992, equalling the 1990 record high. This is the result of an increase in cash receipts and a large, $4-billion inventory adjustment. Higher farm income typically has a positive effect on farm machinery purchases.

Table 39--Trends in U.S. farm investment expenditures and factors affecting farm investment demand

Item	1986	1987	1988	1989	1990	1991P	1992F	1993F
				$ billion				
Capital expenditures:								
Tractors	1.51	2.10	2.48	2.76	2.87	2.36	2.4	2.3-2.6
Other farm machinery	3.09	4.30	4.15	4.92	5.32	5.10	4.8	4.2-4.9
Total	4.60	6.40	6.63	7.68	8.19	7.46	7.2	5.3-7.4
Tractor and machinery repairs	3.43	3.54	3.59	3.96	3.76	3.78	3.9	3.8-4.2
Trucks and autos	1.71	2.17	2.34	2.50	2.52	2.26	2.3	2.3-2.5
Farm buildings 1/	2.14	2.60	2.35	2.45	2.67	2.56	2.0	1.8-2.1
Factors affecting demand:								
Interest expenses	17.1	15.0	14.7	14.7	14.5	13.9	14	12-16
Total production expenses	125.5	128.8	134.3	141.2	145.1	144.9	144	143-149
Outstanding farm debt 2/ 3/	166.6	153.7	148.5	146.0	145.1	147.0	147.8	149-151
Farm real estate assets 2/	613.0	658.6	682.1	703.5	712.6	705.6	704.5	704-710
Farm nonreal estate assets 2/	234.7	252.9	269.9	283.3	295.3	298.5	306.5	306-311
Farm assets 2/	847.7	911.5	952.0	986.8	1,007.9	1,004.1	1,011.0	1,010-1,021
Agricultural exports 4/	26.3	27.9	35.4	39.6	40.1	37.5	42.3	41.5
Cash receipts	135.2	141.8	151.1	161.0	169.9	167.3	169	165-172
Net farm income	31.0	39.7	41.1	49.9	51.0	44.6	51	42-48
Net cash income	46.7	55.8	58.1	58.9	61.3	58.0	60	58-64
Direct government payments	11.8	16.7	14.5	10.9	9.3	8.2	8	9-13
				Million acres				
Idled acres 5/	48.1	76.2	77.7	60.8	61.6	64.5	53.7	58
				Percent				
Real prime rate 6/ 7/	5.7	5.0	5.4	6.5	5.7	4.4	3.6	na
Nominal farm machinery and equipment loan rate 7/	12.2	11.5	11.7	12.8	12.3	11.3	9.3	na
Real farm machinery and equipment loan rate 6/	9.4	8.0	8.4	8.4	8.0	7.2	6.7	na
Debt-asset ratio 8/	19.7	16.9	15.6	14.8	14.5	14.6	14.6	14.8

1/ Includes service buildings structures, and land improvements. 2/ Calculated using nominal dollar balance sheet data, including farm households for December 31 of each year. 3/ Excludes CCC loans. 4/ Fiscal year. 5/ Includes acres idled through commodity programs and acres enrolled in the Conservation Reserve Program. 6/ Deflated by the GDP deflator. 7/ Average annual interest rate. From the quarterly sample survey of commercial banks: Agricultural Financial Databook, Board of Governors of the Federal Reserve System. 8/ Outstanding farm debt divided by the sum of farm real and nonreal estate asset values.
P-preliminary. F-forecast. na-not available.

Source: Agricultural Income and Finance, Situation and Outlook Reports, ERS; and other ERS sources.

Farm Equity

Farm equity, the net worth of the farm sector, is derived from total assets, minus debt. Total farm equity is projected to increase in 1992. Increased equity implies more collateral to finance farm machinery loans.

Assets, at an all-time high of $1,089 billion in 1981, decreased to a 6-year low of $848 billion in 1986, and then climbed to $1,008 billion in 1990. Assets are composed of both real estate and non-real estate, such as livestock, household items, and machinery. Forecast at $1,011 billion for 1992, assets were still below the 1981 high. While total 1992 assets were up, real estate assets were down $8.1 billion from 1990. The increase in total 1992 assets was primarily due to larger household and financial assets. Total assets will likely increase again in 1993.

Farm debt, at an all-time high in 1983 ($207 billion), has since decreased every year until 1990 ($145 billion). In 1991, debt rose to $147.0 billion and was up slightly to $147.8 in 1992. Lower debt improves farmers' borrowing position with lenders.

A common indicator of the economic health of the farm sector is the debt-asset ratio. From an all-time-high ratio of 21 in 1985, it fell to 14.6 in 1991 and is expected to hold steady in 1992. Lower debt-asset ratios have not been in effect since the early 1960's. The 1993 debt-asset ratio will probably rise slightly because debt is forecast to increase faster than assets. The lower the debt-asset ratio, the more favorable the borrowing position of farmers.

Prices

Farm tractor and machinery prices rose for the fifth consecutive year in 1992 (table 40). The October 1992 prices-paid index (1977=100) for tractors was 224, 13 points above 1991. Prices for other machinery and trucks rose 9 and 18 points, respectively. However, the price index for all production items was nearly constant, primarily due to declines in prices of fertilizer and feeder livestock, and lower interest rates. Increases in farm machinery prices have a dampening effect on demand.

While prices paid for farm machinery were increasing, the July 1991-92 prices-received index for all farm products was down from 139 to 137 (1977=100). Decreased commodity prices, and farmers' anticipation of lower prices, discourage purchases of farm machinery and equipment.

Commodity Exports

Another factor that affects purchases of farm machinery is commodity exports. Commodity exports were $42.3 bil-

Table 40--Prices paid for trucks, tractors, and other farm machinery

Year	Trucks and autos	Tractors and self-propelled machinery	Other machinery	Production items, interest, taxes, & wage rates
		1977 = 100		
1980	123	136	132	139
1981	143	152	146	151
1982	159	165	160	158
1983	170	174	171	159
1984	182	181	180	161
1985	193	178	183	156
1986	198	174	182	150
1987	208	174	185	152
1988	215	181	197	160
1989	223	193	208	167
1990	231	202	216	172
1991	244	211	226	175
1992 July	262	217	234	176
1992 Oct. R	262	224	235	176

R-revised.

Source: National Agricultural Statistics Service, USDA.

lion in 1992, up from $37.5 billion in 1991. The 1993 forecast is down slightly at $41.5 billion. At that level, commodity exports would still be the second highest in the last 7 years. Wheat, feedgrains, oilseeds, and cotton compose the major portion of commodity exports. Commodity imports were $24.3 billion in 1992 and are forecast at $24.0 billion in 1993. They are composed largely of livestock products and vegetables. Trends in commodity imports and exports are expected to be favorable toward purchases of farm machinery.

Conservation/Reduced Tillage

Increased conservation practices affect purchases of farm machinery. Farmers are required by the Food Security Act of 1985 to have conservation plans for highly erodible land in operation by 1995 to maintain eligibility for USDA's commodity program benefits. To comply, farmers are adopting conservation tillage measures such as no-till, mulch-till, and ridge-till, all of which require fewer tillage operations than conventional methods, and consequently, less hours of use for tractors and machinery (figure 3). Decreased hours mean fewer equipment purchases are warranted. On the other hand, more sales of the specialized equipment that is needed for conservation tillage operations can be expected.

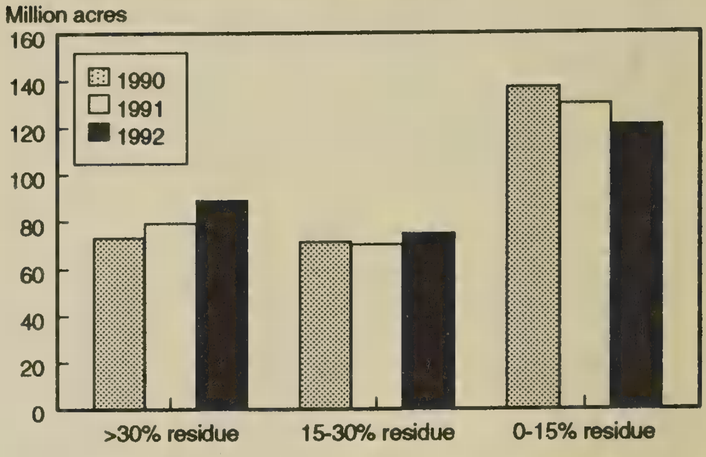
The U.S. Department of Commerce (DOC) reports increased sales of conservation, or reduced-tillage, types of equipment that leave a previous crop residue of 30 percent or greater on the soil surface. These include coulters, disk openers, row cleaners, in-row chisels, and sweeps. Manufacture of moldboard plows has decreased from 60,000 units in 1970 to 6,300 in 1991 (DOC). Use of the moldboard plow is representative of conventional tillage that leaves less than 15-percent residue on the surface.

Farm Machinery Trade

The major category of U.S. exports of farm machinery has been equipment and component parts (table 41). Tractors, combines, and livestock equipment make up most of the remaining exports. Tractors amounted to over one-half of all U.S. imports of farm machinery.

U.S. exports of farm machinery were estimated at $3.2 billion in 1992, according to the DOC (table 42), up 6.3 percent from 1991. The biggest increases in exports were to Canada and Australia. Exports to the European Community decreased 7.6 percent. Major export markets included South and Central America, Japan, and Saudi Arabia. More than one-fourth of the machinery manufactured in

Figure 3
Tillage Practices on Planted Acres



Source: Conservation Technology Information Center

Table 41--Farm machinery exports and imports.

Item	1990	1991	January-July 1991	January-July 1992
		Million dollars		
Exports:				
Total	3,147	2,961	1,778	1,922
Tractors 1/	398	390	229	277
Tractors, used 1/	39	40	25	23
Combines/harvesters	292	279	176	178
Balers	72	59	39	42
Mowers	42	46	33	36
Haying equipment	31	23	18	16
Plows 2/	10	11	5	6
Harrows/cultivators	13	16	9	11
Spraying equipment	55	89	50	60
Seed/planting equip.	70	73	46	56
Livestock equipment	308	244	150	176
Parts & components	1,816	1,691	997	1,041
Imports:				
Total	2,364	1,850	1,216	1,195
Tractors 1/	1,225	972	663	620
Tractors, used 3/	13	12		
Combines/harvesters	72	57	40	37
Balers	10	8	6	4
Mowers	77	60	46	43
Haying equipment	14	14	12	5
Plows 2/	26	20	11	7
Harrows/cultivators	136	77	46	36
Spraying equipment	32	32	23	29
Seed/planting equip.	63	38	24	26
Livestock equipment	103	82	52	51
Parts & components	592	477	294	336

1/ Does not include track-laying tractors.
2/ Includes moldboard, disk, and other plows.
3/ January-July, unavailable.

Source: International Trade Commission and official statistics of the U.S. Department of Commerce.

Table 42--U.S. farm machinery trade situation, 1986-1992

Year	Ship-ments	Exports	Imports	Trade surplus	Domestic supply	Ship-ments exported	Domestic supply imported
	$ billion					Percent	
1989	10.4	2.9	2.3	0.6	9.8	28	23
1990	11.5	3.2	2.6	0.6	10.9	27	23
1991	11.2	3.0	2.0	1.1	10.1	27	19
1992E	9.9	3.2	1.9	1.3	8.6	32	22
1993F	10.0	3.3	1.8	1.5	8.5	33	22

E-estimated. F-forecasted.

Source: U.S. Industrial Outlook 1993, International Trade Administration.

the U.S. is exported. Exports, as a percent of U.S. shipments, have been increasing since 1989 and are forecast to reach 33 percent in 1993.

Farm machinery imports declined for the second year in a row. Imports for 1992 were $1.9 billion, a decline of 4.1 percent from 1991. More than 60 percent of U.S. farm machinery imports are tractors and parts, mostly for below-100-horsepower tractors according to DOC. John Deere reintroduced U.S. manufacture of 40-100 horsepower tractors, accounting for part of the decline in imports. Major suppliers of imports were Germany, the United Kingdom, Japan, and Canada. Imports, as a percent of domestic supply, have held at 22-23 percent from 1989 to 1992, dipping to 19 percent in 1991.

The trade surplus in farm machinery was $1.1 billion in 1991. In 1992 it will be an estimated $1.3 billion. Exports of farm machinery have exceeded imports for the last 4 years. The outlook for 1993 is for another increase in exports to about $3.3 billion and a slight decrease in imports to about $1.8 billion, for a trade surplus of $1.5 billion.

References

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Seeds

Seed Use and Seed Prices-Paid Index Are Likely To Rise in 1993

In the 1992/93 crop year, total seed use for eight major crops is expected to be 6.1 million tons, up 2 percent from the previous year. The prices-paid index for all seeds, on the other hand, is likely to increase less than 1 percent in 1993.

Consumption

The two most important determinants of seed consumption are planted acreage and seeding rates per acre. Because seeding rates change very slowly from year to year, planted acreage becomes the major factor affecting variations in seed use. In 1993, wheat, barley, and oats planted acreage are expected to increase because of a decrease in the wheat acreage reduction program (ARP) from 5 percent in 1992 to zero percent in 1993. Oats and barley also have zero ARP's for 1993. Corn planted acreage, on the other hand, is expected to decrease because of an increase in the corn ARP from 5 percent in 1992 to 10 percent in 1993.

In the 1992/93 crop year, total seed use for eight major crops is expected to be 6.1 million tons, up 2 percent from the previous year, because the increased seed demand for wheat, barley, and oats will more than offset the expected decline in seed demand for corn, sorghum, and cotton, due to lower planted acreages (table 43). Seed use was estimated at 5.9 million tons in 1991/92.

Prices

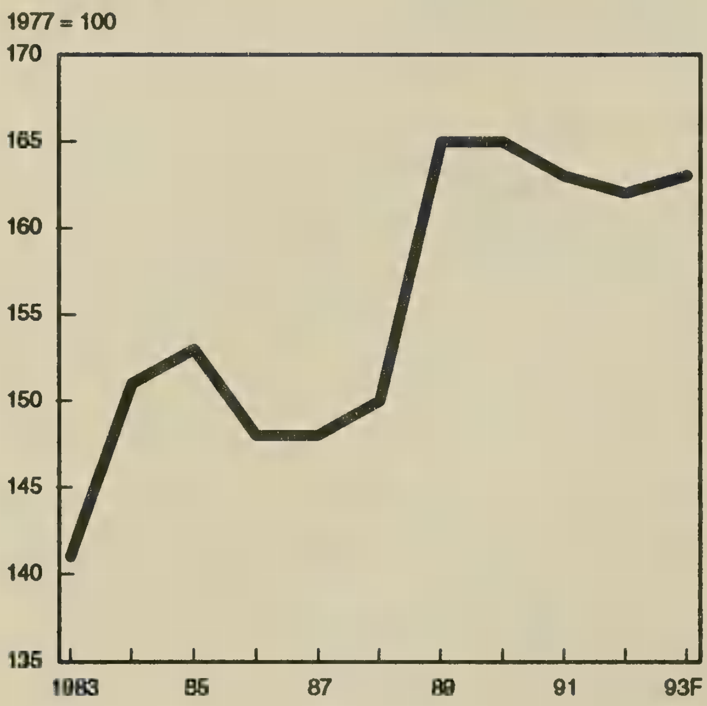
Higher corn, grain sorghum, small grains, and cotton seed prices in 1992 were offset by generally lower prices for seed potatoes, soybeans, and most of the forage seeds. As a result, USDA's prices-paid index for all seeds, 162, was 1 point lower than the previous year. Adequate seed supplies, a modest increase in seed demand, and small commodity price movements are expected to limit the increase in the seed price index to less than 1 percent in 1993 (figure 4). Seed prices, especially for nonhybrid crops, tend to follow commercial crop prices, and (with the exception

Table 43--Seed use for major U.S. field crops 1/

Crops	1989/90	1990/91	1991/92 2/	1992/93 3/	1991/92-1992/93
	-----------	1,000 tons	---------		% change
Corn	529	540	566	528	-7
Sorghum	36	39	48	47	-2
Soybeans	1,664	1,701	1,700	1,717	1
Barley	324	350	307	338	10
Oats	374	306	290	319	10
Wheat	3,009	2,709	2,811	2,895	3
Rice	160	168	174	174	0
Cotton 4/	94	108	102	98	-4
Total	6,190	5,921	5,998	6,116	2

1/ Crop marketing year. 2/ Preliminary. 3/ Projected based on Table 1 acreage. 4/ Upland cotton.

Figure 4
Seed Price Index



F = Forecast.

of wheat and oats) commodity prices in 1993 are forecast to fall below 1992.

Plentiful forage seed supplies, relative to only a modest increase in demand due to slower growth of the Conservation Reserve Program (CRP), contributed to a decline in forage seed prices in 1992. In the 1993 crop year, 1.1 million cropland acres are likely to be enrolled, compared to 998,211 acres in 1992, an increase of 10 percent. This CRP-related increase in grass seed demand may not translate into price increase, as forage seed supplies are expected to be plentiful in 1993. Moreover, 18 percent of this area is required to be planted to trees compared to 6 percent in previous years (1985-90).

Seeding Rates and Costs Per Acre

The two major factors which determine seed cost per acre are seeding rates and seed price. However, per acre seed costs vary by states and by crops, as there are variations in seeding rates according to geographic regions and moisture conditions. Areas where moisture is plentiful in the growing season, due either to heavy rain or irrigation, support heavier seeding rates. Higher seeding rates mean higher seed costs per acre.

Corn

In 1992, the average seeding rate for the 10 major corn producing states was 25,304 kernels per acre, up 1 percent from a year earlier. The average seed cost per acre was $21.35, up 3 percent from 1991, reflecting higher (2 percent) seed corn prices and higher corn seeding rates. The average plant population per acre for these states was similar to 1991.

Among surveyed states, Minnesota and Ohio had the highest seed costs because of higher seeding rates. South Dakota, on the other hand, had the lowest seeding rate and, consequently, the least seed cost per acre (table 44).

Soybeans

Soybeans are grown in 14 major states in the United States. These states accounted for 82 percent of U.S. soybean acres in 1992. In these states, the average seeding rate was 65 pounds per acre, 1.6 percent higher than in 1991. The average seed cost per acre was $15.40, up 2 percent, reflecting higher seeding rates (table 45). Most of the northern soybean growing states, which have higher seeding rates and yields, have a higher seed cost per acre. A majority of the southern states, on the other hand, have lower seeding rates and, consequently, a lower seeding cost per year.

The share of 1992 acres planted with purchased seed was 73 percent, the same as in 1991. Farmers preferred to use purchased, rather than homegrown, seed to plant soybean acres in the surveyed states. However, the share of acres planted with purchased seed varied widely among the surveyed states, ranging from 48 percent in Georgia to 80 percent in Ohio. Differences in seed cost and yield often de-

Table 44--Corn for grain seeding rates, plant population, and seed cost per acre, 1992 1/

States	Acres planted 2/	Rate per acre	Plant population per acre	Cost per acre
	1,000	Kernels	Number	Dollars
Illinois	11,200	25,628	23,100	21.51
Indiana	6,100	25,041	23,200	19.71
Iowa	13,400	25,790	23,300	21.86
Michigan	2,700	24,802	21,700	20.06
Minnesota	7,200	27,175	24,600	23.76
Missouri	2,450	22,567	18,800	19.52
Nebraska	8,300	25,124	21,900	21.95
Nonirrigated	2,700	19,275	nr	16.39
Irrigated	5,600	27,953	nr	24.64
Ohio	3,800	26,399	23,300	22.68
South Dakota	3,800	20,019	17,800	17.56
Wisconsin	3,900	26,194	22,600	20.40
1992 average	62,850	25,304	22,030	21.35
1991 average	60,350	24,906	22,080	20.79
1990 average	58,800	24,700	21,040	20.50

nr - Not reported.
1/ States planted 79 percent of U.S. corn acres in 1992. 2/ Preliminary.

Table 45--Soybean seeding rates, seed cost per acre, and percent of seed purchased, 1992 1/

Region/States	Acres planted 2/	Rate per acre	Cost per acre 3/	Acres with purchased seed
	1,000	Pounds	Dollars	Percent
Northern:				
Illinois	9,500	66	17.01	74
Indiana	4,550	68	15.54	82
Iowa	8,100	62	16.99	80
Minnesota	5,500	70	15.28	71
Missouri	4,300	65	13.71	58
Nebraska	2,500	60	16.23	83
Ohio	3,700	80	17.11	72
Southern:				
Arkansas	3,200	57	11.10	61
Georgia	650	48	10.10	71
Kentucky	1,180	66	14.67	64
Louisiana	1,200	55	14.37	96
Mississippi	1,850	51	10.95	84
North Carolina	1,400	63	14.11	67
Tennessee	1,000	56	10.09	55
1992 average	48,630	65	15.40	73
1991 average	49,650	64	15.07	73
1990 average	48,250	62	14.20	71

1/ States planted 82 percent of U.S. soybean acres in 1992. 2/ Preliminary. 3/ Based on data from farmers who used purchased seed.

termine the choice between purchased and homegrown seed.

Spring and Durum Wheat

In 1992, the average spring wheat seeding rate, 91 pounds per acre, was slightly higher than a year earlier. The average seed cost per acre was $8.39, up 29 percent from 1991, reflecting a 28-percent increase in the spring wheat seed price. Moreover, the seeding rate was also higher compared with a year earlier (table 46).

Spring wheat seed costs per acre varied among the surveyed states. This was attributed to variations in seeding rates and seed prices among states, due to geographic location and availability of moisture during the growing season. Minnesota, with a seeding rate of 110 pounds per acre, had the highest seeding rate and, consequently, the highest cost, $10.67 per acre. Montana, on the other hand, had the least cost per acre, $6.35, due to the lowest seeding rate, 64 pounds. These states were in similar relative positions in 1991. Farmers planted 41 percent of spring wheat acres with purchased seed, the remainder was planted with homegrown spring wheat seed.

The average seed cost for the 1992 durum wheat crop was $7.56, up 11 percent, reflecting higher seed prices (table 46). The seeding rate, however, was lower than a year earlier but about the same as in 1990. Most of the durum wheat acres were planted with homegrown seed, with only 36 percent planted with purchased seeds.

Cotton

In 1992, the average seeding rate for cotton was 16 pounds, slightly lower than a year earlier. The average seed cost, $8.74 per acre, was higher than the previous year because 1992 cottonseed prices were 2.6 percent higher (table 47).

Seeding rates and seed costs for cotton varied among surveyed states. California had the highest seed cost per acre, whereas Texas had the highest seeding rate per acre. California, with a lower seeding rate than Texas, had higher seed costs per acre, the result of higher cottonseed prices in California. Cottonseed prices in Texas, on the other hand, are lower because of intense competition among suppliers due to a large number of cottonseed varieties.

The situation in Texas is, therefore, the opposite of that in California. Although it has a higher seeding rate than California, seed cost per acre is lower due to lower seed prices. Farmers in the surveyed states used purchased seed on 74 percent of 1992 cotton acres, higher than a year earlier but close to that of 1990.

Table 46--Spring and durum wheat seeding rates, seed cost per acre, and percent of seed purchased, 1992 1/

States	Area planted 2/	Rate per acre	Cost per acre 3/	Acres with purchased seed
	1,000	Pounds	Dollars	Percent
Spring:				
Minnesota	2,800	110	10.67	71
Montana	2,650	64	6.35	32
North Dakota	9,200	93	7.78	38
South Dakota	2,700	92	7.59	30
1992 average	17,350	91	8.39	41
1991 average	13,500	89	6.52	32
1990 average	15,800	88	8.40	39
Durum:				
North Dakota	2,200	96	7.56	36
1992 average	2,200	96	7.56	36
1991 average	3,000	100	6.66	27
1990 average	3,100	97	7.50	27

1/ States planted 93 percent of U.S. spring wheat and 89 percent of U.S. durum wheat acres in 1992. 2/ Preliminary. 3/ Based on data from farmers who used purchased seed.

Table 47--Cotton seeding rates, seed cost per acre, and percent of seed purchased, 1992 1/

States	Acres planted 2/	Rate per acre	Cost per acre 3/	Acres with purchased seed
	1,000	Pound	Dollars	Percent
Arizona	320	13	7.65	94
Arkansas	980	12	7.65	96
California	1,000	17	11.23	89
Louisiana	900	11	7.26	90
Mississippi	1,350	12	7.84	98
Texas	5,650	18	7.74	47
1992 average	10,200	16	8.74	74
1991 average	10,860	17	8.11	66
1990 average	9,730	17	7.80	70

1/ States planted 77 percent of U.S. upland cotton acres in 1992. 2/ Preliminary. 3/ Based on data from farmers who used purchased seed.

Rice

Arkansas and Louisiana are the two leading rice-producing states. The two accounted for 64 percent of total U.S. rice acreage in 1992. The average seeding rate was 121 pounds per acre in 1992. Louisiana had a higher seed cost per acre, $22.91, because of the higher seeding rate. Arkansas had a lower seeding rate and, consequently, had a lower seeding cost of $20.02 per acre (table 48).

Farmers in both states planted rice acreage mostly with purchased seeds. The average share of rice acreage planted with homegrown seeds was only 19 percent in 1992.

U.S. Seed Exports and Imports

Corn Seed Exports

The volume of U.S. corn seed exported to the 12 major importers fell to 36,253 metric tons in the first 9 months of 1992, a 23-percent decline from the corresponding period in 1991. in the first 9 months of 1992 (table 49). These

Table 48--Rice seeding rates, seed cost per acre, and percent of seed purchased, 1992 1/

States	Acres planted 2/	Rate per acre	Cost per acre 3/	Acres with purchased seed
	1,000	Pounds	Dollars	Percent
Arkansas	1,350	118	20.02	76
Louisiana	600	129	22.92	94
1992 average	1,950	121	21.05	81
1991 average	1,880	126	20.13	81
1990 average	1,800	126	20.80	84

1/ States planted 64 percent of U.S. rice acres in 1992. 2/ Preliminary. 3/ Based on data from farmers who used purchased seed.

Table 49--U.S. corn seed exports by volume

Country	1989	1990	1991	January-September 1991	January-September 1992	Change 91-92
	--Metric tons---			--Metric tons--		%
Canada	1,548	4,076	7,561	3,850	6,411	67
Mexico	10,205	10,329	7,963	7,056	8,295	18
France	2,873	9,666	10,953	4,164	2,438	-41
Germany	522	1,796	8,822	8,150	1,183	-85
Spain	1,836	4,132	2,076	1,332	1,821	37
Italy	12,168	20,889	21,773	11,004	11,985	9
Netherlands	351	2,437	10,354	1,973	247	-87
Greece	1,999	1,828	4,072	2,814	2,163	-23
Romania	107	1,050	2,532	2,530	191	-92
USSR	0	2,459	3,569	3,569	353	-90
Turkey	245	59	171	171	388	127
Japan	1,051	1,431	1,491	647	778	20
Subtotal	32,905	60,152	81,337	47,260	36,253	-23
Total all countries	36,859	70,366	93,722	57,138	41,830	-27

Source: U.S. Department of Commerce, Bureau of the Census, Foreign Trade Division.

countries accounted for 87 percent of U.S. corn seed exports during this period. U.S. corn seed exports to all countries, on the other hand, fell 27 percent during the same 9-month period.

Shipments of U.S. corn seed to Canada, Mexico, Spain, and Italy increased, 67, 18, 37, and 9 percent, respectively. However, the gains were not enough to offset sharp declines in exports to the former USSR and East European countries which have limited buying power due to scarce hard currency.

Corn Seed Imports

Canada, Argentina, Chile, and Hungary are the major suppliers of corn seed. These countries supplied 96 percent of total U.S. corn seed imports in the first 9 months of 1992, compared to the corresponding period of 1991. However, these imports constitute a very small part of total U.S. corn seed consumption.

The volume of corn seed imports from these countries, in the first 9 months of 1992, was 20,829 metric tons, a 166-percent jump compared to a year earlier (table 50). This sharp increase was attributable to large shipments of off-season production from Argentina and Chile to satisfy an increased demand in 1992 that resulted from increased acreage.

Soybean Seed Exports

Italy, France, Mexico, and Canada remained important buyers of soybean seeds. During the first 9 months of 1992, 91 percent of U.S. soybean seed was exported to these countries. The volume of soybean seed exports was 67,142 metric tons, a 7-percent decline in the first 9 months of 1992, compared with the same period of 1991. In the same period of 1992, total exports to all countries declined 6 percent (table 51).

Table 50--U.S. corn seed imports by volume

Country	1989	1990	1991	January-September 1991	January-September 1992	Change 91-92
	---Metric tons---			-Metric ton-		%
Canada	7,753	8,010	6,857	4,337	2,121	-51
Argentina	2,457	511	138	138	4,821	3393
Chile	7,000	4,509	3,406	3,367	13,496	301
Hungary	3,708	881	0	0	391	na
Subtotal	20,918	13,911	10,401	7,842	20,829	166
Total all countries	22,672	13,996	10,978	8,323	21,588	159

na = Not applicable

Source: U.S. Department of Commerce, Bureau of the Census, Foreign Trade Division.

Table 51--U.S. soybean seed exports by volume

Country	1989	1990	1991	January-September 1991	January-September 1992	Change 91-92
	----Metric tons----			-Metric tons-		%
Canada	390	449	425	425	1,178	177
Mexico	100,380	36,731	4,827	4,542	31,688	598
France	1,698	4,827	4,272	3,948	584	-85
Italy	20,185	55,937	65,571	56,757	32,389	-43
Turkey	2,777	2,835	1,838	1,838	7	-100
Japan	1,608	2,325	6,947	4,880	1,296	-73
Subtotal	127,038	103,104	83,880	72,390	67,142	-7
Total all countries	128,582	106,991	91,004	78,259	73,659	-6

Source: U.S. Department of Commerce, Bureau of the Census, Foreign Trade Division.

U.S. soybean seed exports to Mexico and Canada increased sharply in the first 9 months of 1992, compared with the corresponding period of 1991. These gains, however, were overshadowed by a decline in exports to Italy, France, Turkey, and Japan which resulted in an overall decline in U.S. soybean seed exports.

Total Exports

In the first 9 months of 1992, the value of total seed exports fell 1 percent to $447 million, compared with the same period of 1991. This drop largely reflects declines of 1, 6, 17, and 33 percent in vegetable, corn, soybean, and sugarbeet seed exports, respectively (table 52). The value of other seed exports also declined 12 percent during the same period of time.

Table 52--Exports and imports of U.S. seed for planting

Item	1989	1990	1991	January-September 1991	January-September 1992	Change 91-92
	-----$ million-----					%
Exports:						
Forage	96	104	101	71	78	10
Vegetable	153	176	220	142	140	-1
Flower	11	13	14	8	12	50
Corn 2/	68	138	181	109	102	-6
Grain sorghum	55	27	28	22	28	27
Soybean	54	45	41	36	30	-17
Tree/shrub	4	2	2	1	2	100
Sugarbeet	1	2	3	3	2	-33
Other	68	81	82	60	53	-12
Total	510	588	672	452	447	-1
Imports:						
Forage	44	35	31	25	35	40
Vegetable	56	60	79	58	64	10
Flower	24	23	24	17	20	18
Corn 3/	37	18	15	11	31	182
Tree/shrub	2	2	2	1	1	0
Other	6	9	14	11	10	-9
Total	169	147	165	123	161	31
Trade balance	341	441	507	329	286	-13

1/ Not sweet, not food aid. 3/ Certified

Source: U.S. Department of Commerce, Bureau of the Census, Foreign Trade Division.

Total Imports

The value of total seed imports rose 31 percent to $161 million in the first 9 months of 1992, compared with the same period of 1991 (table 52). This increase was primarily attributable to gains of 182, 40, 18, and 10 percent, respectively, in corn, forage, flower, and vegetable seed imports. The value of other seed imports, however, declined 9 percent in the same period. The U.S. net seed trade balance fell 13 percent to $286 million in the first 9 months of 1992, compared with the same period in 1991.

Economic and Environmental Impacts of Alternative Cropping Sequences in Michigan

by

Tracy Irwin-Hewitt and Luanne Lohr[1]

Abstract: A method for designing and simulating economic returns and environmental characteristics of alternative production systems is developed. A net present value model was constructed for intertemporal economic comparisons, and the SMART-FRMS computer system was used to simulate environmental characteristics of the cropping sequences. A site-specific, field-level simulation indicated that the no-till systems were more profitable, with less environmental impact than the conventional system. The nitrogen from anhydrous ammonia was determined less expensive than the nitrogen from hairy vetch. Including canola as an alternative crop did not significantly change the profitability of the system.

Keywords: Cropping sequences, rotations, net present value analysis, environmental impact.

Introduction

The pre-1985 decisionmaking environment faced by farmers was distinctly different than the current situation. Before 1985, soil conservation measures were not required of farmers in federal farm program legislation. The basic objectives of federal farm legislation during the pre-1985 period were to support farm income and to secure a stable and reasonably priced food and fiber supply *(1)*. The policies were implemented by supporting commodity prices and farm income, and by controlling the supply of the commodities produced. However, these policies may have had unintended consequences on environmental quality.

In a 1984 report to Congress, the Environmental Protection Agency (EPA) found agriculture to be the largest nonpoint source polluter of surface water in the United States (*2*). Farmers and nonfarmers began to question the rate of topsoil depletion from agricultural production, the amount and type of chemicals used in farming, as well as farming practices and their relationship to the safety of drinking water and pesticide residues on food. In response, the 1985 Food Security Act introduced environmental components tied to agricultural commodity programs. Changes in farmers' production practices may be necessary to meet these requirements.

This study develops a method for designing and simulating the economic returns and environmental characteristics of alternative production systems specified through farmer-researcher collaboration. This approach exploits the farmers' self-identified constraints, whether monetary or nonmonetary, without requiring explicit modeling of the constraints.

Project Description

This study was part of an interdisciplinary research project designed to analyze sustainable agriculture in Michigan. The economic component focused on a field level analysis[2] of alternative cropping sequences (or rotations) selected by a participating farmer in collaboration with researchers. The fields and rotations used in the analysis were selected by considering crops well-suited to the area, soil type, field history, farmer interest and information needs, and research needs.

The rotations were then characterized in economic and environmental terms so the farmer could make the best decision based on nonmonetary (internal) constraints and objectives, such as the desire to fully employ family labor, worker safety, and land stewardship values.

The results from one of the fields is discussed in this report. This field had six cropping sequences developed to facilitate three comparisons: a tillage comparison, a fertilizer comparison, and an alternative crop comparison (table A-1). The crops are under no-till cultivation except for canola and those in rotation Z, which are conventionally tilled3. Also, the rotations that included a hairy vetch interseeding assume one mechanical cultivation for weed control.

The Data and Other Assumptions

The data used in this analysis came from several sources. When possible, actual farm data were used for field characteristics (slope, slope length, organic matter, etc.) and for expected yield and field treatments. However, when actual figures were unavailable, expert opinion (based on existing

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[2] The fields selected represent 8 percent of tillable land on the farm.

[3] Based on farmer preference.

Table A-1 -- Cropping sequences selected for analysis

Rotation	Year 1	Year 2	Year 3	Year 4	Year 5
A	Corn	Soybeans			
B	Corn	Corn	Soybeans	Wheat	
C	Corn w/vetch 20-pound nitrogen credit	Corn	Soybeans	Wheat	
D	Corn w/vetch 90-pound nitrogen credit	Corn	Soybeans	Wheat	
E	Corn	Corn	Soybeans	Wheat	Canola
1/ Z	Corn	Soybeans			

1/ Rotation Z is under conventional cultivation.

literature and personal experience) was used. The experts were primarily members of the interdisciplinary team, including specialists in sustainable agriculture, nutrient management, crop production, soil conservation, farm management, and environmental and public policy. When opinions differed, another collaborator was consulted and the more conservative estimate was used in the analysis. This approach avoided exaggerated claims for the hypothetical systems.

A net present value model (NPV) was constructed for intertemporal comparisons of the cropping sequences. It was calculated using variable production costs and market prices (in 1992 dollars) for the commodities, which were assumed constant over the farmer's planning horizon. Annual fixed-cost payments were not used in the NPV calculation because this was a field-level study; however, annual machinery repairs and maintenance costs were included.

Farm program incentives and deficiency payments were not part of this analysis. No-till corn and soybean yields were assumed to be 10 bushels per acre less than the conventionally tilled system *(3)*. Hairy vetch was valued as a nitrogen source and as an erosion inhibitor. Erosion was included as an on-farm production cost of lost nutrients, assumed to be valued at $6.00 per ton. Off-farm erosion costs were not calculated. Finally, production from the systems were assumed not to impact commodity prices because this was a single field analysis.

The BUDGETOR component of the SMART-FRMS computer system was used to develop partial crop budgets for each year of the sequence, based on the previous crop and field history *(4,5)*. The cash flows generated by the budgets were organized into the NPV model. The model assumed each system reached equilibrium after a one-time transition period equal to one cycle of the rotation. The equilibrium rotation was extended into perpetuity so rotations with unequal lengths could be compared. The NPV was calculated at a 5-percent discount rate and converted to its equivalent annualized cash flow for presentation to the farmer. This figure represents the annuity equivalent to the discounted annual cash flows generated by the system.

The PLANETOR component of the SMART-FRMS computer system was used for environmental simulations of the cropping sequences *(6)*. Its indicators include expected erosion, residual nitrogen, and risk of water-quality damage. Expected erosion is estimated with the Universal Soil Loss Equation and categorized as "high", "medium", or "low" relative to the soil-specific tolerable level determined by USDA's Soil Conservation Service (SCS).

The second indicator estimates the residual nitrogen remaining in the soil after the production cycle. The quantity estimated is also categorized as "high", "medium" or "low" to indicate the potential risk to water quality from residual nitrogen. If there was an average of less than 25 pounds of residual nitrogen at expected yields, the nitrogen in the system was considered a "low" risk to water quality. Systems that averaged between 25 pounds at expected yields and 50 pounds at optimistic yields, were considered a "medium" risk, while anything over 50 pounds at optimistic yields was considered "high".

The third indicator estimates the overall risk to water quality based on the soil and chemical characteristics of the system. The program uses information on soil adsorption, water solubility, and persistence of production chemicals; as well as the hydrological group, organic matter and erodibility of the soil. The results are categorized into "high", "medium" or "low" to indicate the potential of water-quality damage from the entire production system. These indicators were the basis of the environmental comparisons of the systems (table A-2).

Tillage Comparison (A and Z)

Rotation A and rotation Z were corn-soybean rotations designed to compare tillage systems, rotation A was no-till and rotation Z was conventionally tilled. Table A-2 shows the equivalent annualized cash flow generated by rotation A was $120.79 per acre, while rotation Z generated $96.08 per acre—a difference of $24.71 per acre.

This difference was largely attributed to higher labor, fuel, and erosion costs in rotation Z. Labor costs were $43.00 per acre higher for corn production in rotation Z, due to additional tillage used in seedbed preparation. The extra tillage also contributed to higher fuel and erosion costs. Fuel costs were $7.00 per acre higher in rotation Z and erosion

Table A-2 -- Economic and environmental indicators of the rotations

Rotation	Equivalent annualized cash flow ($/acre/year)	Average expected erosion 1/ (H,M,L) (tons/ac/yr)	Water quality 2/ (H,M,L)	Average residual nitrogen 3/ (H,M,L) (lbs/acre/yr)
A	120.79	Low 0.25	High	Medium 35
B	102.22	Low 0.37	High	Medium 41
C	92.99	Low 0.31	High	Medium 41
D	96.37	Low 0.31	High	Medium 41
E	102.30	Low 0.50	High	Medium 41
Z	96.08	Low 2.04	High	Medium 51

1/ Low: expected erosion is less than or equal to 90 percent of the tolerable soil loss (5 tons/acre/year). Medium: expected erosion is between 90 and 200 percent of the tolerable soil loss. High: expected erosion is greater than 200 percent of the tolerable soil loss. 2/ This is calculated by combining specific characteristics of the soil and the chemicals used in the rotation; for example, the hydrological group and erodibility of the soil, persistence and water solubility of the chemicals. 3/ Low: less than 25 pounds at expected yields. Medium: between 25 pounds at expected yields and 50 pounds at optimistic yields. High: greater than 50 pounds at optimistic yields.

costs were $11.00 higher. The additional production costs associated with rotation Z made it less profitable than A, even though yields were assumed higher. However, non-optimal management of either system could change their relative profitability.

As shown in table A-2, rotation A and Z both received a "low" rating for the amount of expected erosion. This indicates that both systems produced less erosion than the soil-specific tolerable level determined by USDA's SCS. However, since tillage affects the amount of cover remaining on a field, the average expected erosion produced in rotation Z (2.04 tons per acre per year) was significantly more than produced in A (0.25 tons).

Both systems generated a "high"-risk rating for potential water-quality damage. This was expected because the systems differ primarily by tillage. However, table A-2 shows that rotation Z was expected to produce an average of 51 pounds of residual nitrogen per acre per year, while A was expected to produce 35. This was caused by higher application rates in the conventional system, because nitrogen credits from the previous crop were not fully credited, as in existing systems in Michigan.

Fertilizer Comparison (B, C and D)

Rotations B, C, and D compared hairy vetch and anhydrous ammonia as nitrogen sources. Table A-2 shows that the cropping sequences were identical, except rotations C and D had hairy vetch interseeded into first-year corn. The assumed nitrogen contribution of the vetch was 20 pounds per acre for rotation C, and 90 pounds per acre for D. These values were selected by agronomists as the likely range of hairy vetch contribution, based on the physical parameters of the system. The NPV calculations indicated that rotation B had the highest equivalent annualized cash flow, $102.22 per acre per year. Rotation D was second, generating $96.37 per acre per year, while rotation C generated $92.99.

Hence, including hairy vetch in the rotation cost the farmer a cash flow equivalent of approximately $6.00 to $9.00 per acre per year, depending on the assumed nitrogen credit. This difference can be attributed to the relative cost of vetch-produced nitrogen and anhydrous ammonia.

The environmental indicators were slightly different across rotations. Rotations C and D produced less erosion (0.31 tons per acre per year) than rotation B (0.37 tons), because hairy vetch provided additional ground cover. Otherwise, the environmental indicators were the same. Each rotation produced 41 pounds per acre per year of residual nitrogen, and received a "high" rating for water-quality risk.

Cropping Comparison (B and E)

Rotations B and E were designed to compare the effects of extending a corn-corn-soybean-wheat rotation to include canola after wheat. Rotation B, which did not include canola, returned an equivalent annualized cash flow of $102.22 and rotation E generated $102.30, a difference of $0.08 per acre per year. This implies that canola could be a profitable addition to the rotation.

The most noticeable environmental difference between the rotations was in the amount of expected erosion. Because canola was conventionally tilled, crop residue was removed from the soil surface, allowing more erosion. Subsequently, rotation E produced 0.50 tons of erosion per acre per year, while rotation B produced 0.37 tons. The difference between rotations is relatively small; however, because this is an average rate, significantly more erosion is expected in the year canola is produced. The rotations each generated a "high" rating for water-quality risk and produced approximately the same residual nitrogen.

General Comparison (A, B, C, D, E, Z)

Rotation A ranked first among all rotations in economic and environmental terms. It had the highest equivalent an-

nualized cash flow and the lowest environmental impact. In contrast, rotation Z was ranked fifth in economic terms and sixth, or last, in environmental terms. The rankings of the other rotations were mixed. For example, rotation E was second in economic terms and fifth in environmental terms. Similarly, C ranked sixth in profitability but tied for second in erosion and residual nitrogen.

The ordinal environmental ratings were the same for each of the cropping sequences. This was partially due to the similarity of the rotations. However, it was also influenced by current limitations of PLANETOR, the environmental simulation component. PLANETOR is still under development and its environmental capabilities are expected to improve significantly in the next version.

Changes are planned to include specific probabilities of water-quality damage associated with the "high, medium, and low" ratings and estimates of chemical fate and transport. Even so, the program made a significant contribution to this project by providing a method for rating the cropping sequences in environmental terms.

Conclusions

The economic and environmental results of this study indicated that the no-till system was more profitable than the conventional system and had less environmental impact, as measured by the on-farm cost of lost nutrients from erosion, water quality, and residual nitrogen. This suggests that federal programs which promote soil conservation through reduced tillage may decrease agriculture's environmental impact and improve on-farm profits.

Rotations that used hairy vetch as a nitrogen source were significantly less profitable, while producing the same residual nitrogen as an identical rotation using anhydrous ammonia. Therefore, the cost ratio between nitrogen sources must change significantly for this form of organic fertilizer to be widely adopted. If adopted, the environmental results suggest that organic fertilizers, such as hairy vetch, may cause environmental impacts similar to inorganic fertilizers.

Finally, including canola as an alternative crop did not significantly change the profitability of the same rotation without the crop. Since the analysis was conducted in the absence of federal farm legislation, the results suggest a potential for greater crop diversification when production decisions are made independent of participation in farm programs.

The results of this study are based on a number of economic and physical assumptions which are applicable to the specific site used in this analysis. Future research is needed to ascertain whether these assumptions, the methodology, and the conclusions are transferable to other parts of the U.S.

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Pesticide Productivity in Pacific Northwest Potato Production

by

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Abstract: Potato production in Idaho and Washington in 1990 was analyzed to investigate the impact of model specification on estimates of pesticide productivity. Pesticides are defined as the sum of herbicides, insecticides, and fungicides. The results indicate that estimates of pesticide productivity are highly sensitive to model selection (variable definition and functional form), a result which is consistent with the literature. In addition, the results suggest that pesticide productivity may vary according to application timing. If, indeed, pesticide productivity varies by the timing of applications, by identifying the type of applications that render the lowest productivity we can minimize the burden of restricting pesticide use and improve pesticide productivity.

Keywords: Potatoes, pesticide productivity, application timing.

Introduction

Public concern over the hazards to wildlife and human health caused by pesticide use in agriculture has motivated research on the productivity of pesticides. An estimate of pesticide productivity is useful for two reasons (*3*). First, it sheds light on the efficiency, in terms of private costs and returns, of pesticides, and it provides information on the economic framework within which farmers operate. Secondly, it gives an indication of the cost, in terms of foregone output, of limiting pesticide use.

Mixed findings have been reported on pesticide productivity. Many empirical studies concluded that the value of the marginal product of pesticides exceeds the marginal factor cost, suggesting agricultural pesticides are underused (*3*, *4*, *6*). However, some researchers have argued that there is evidence to suggest that pesticides are overused in agriculture (*5*, *7*).

In this study, 1990 potato production in the Pacific Northwest (PNW) region was analyzed to investigate the impact of model specification on estimates of pesticide productivity. The results suggest that pesticide productivity estimates are very sensitive to the specification of the relationship between yields and inputs, especially pesticide inputs. Furthermore, pesticide productivity appears to vary by the timing (before, at, or after planting) of applications. If, indeed, pesticide productivity varies by the timing of applications, by identifying the type of applications that render the lowest productivity we can minimize the burden of restricting pesticide use and improve pesticide productivity.

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Literature

Several empirical studies of agricultural pesticide productivity have been conducted during the past two decades. An analysis of the USDA farm income and expenses data for 1963 indicated that the returns to each dollar of pesticide materials ranged from $3.90 to $5.66, a result which is consistent with the rapid increase in the sales volume of pesticides during the 1960's (*6*). A study of a sample of 57 tree-fruit farms in British Columbia for 1970 concluded that the value of pesticide marginal product is about 12 times the marginal cost (*3*). Such a divergence between revenue and cost was attributed to a constraint on farmers' total expenditures on variable inputs.

The productivity of pesticides applied to cotton production was estimated for five regions in 1964, 1966, and 1969 (*4*). Among the 15 estimated values of pesticide productivity, 13 of them indicated that cotton pesticides were underused. The main conclusion of the study was that cotton pesticide productivity was falling over time in four of the five studied regions. This supports the hypothesis that cotton pests have developed resistances to pesticides over time. The Cobb-Douglas (hereafter, termed log-log) functional form was used to explain the input-output relationship in the three studies reviewed above.

The high pesticide productivity reported in the literature motivated Lichtenberg and Zilberman (*7*) to examine theoretically the relationship between model specifications and productivity estimates. They showed that the log-log model tends to overestimate pesticide productivity, while underestimating the productivity of conventional factors of production, such as nitrogen.

A 1987 version of the USDA farm income and expenses data was analyzed as an empirical utilization of Lichtenberg and Zilberman's theoretical results (*5*). The results indicated both underuse and overuse of pesticides when four

alternative models were fit to the same data, supporting the claim that model specification does matter in the estimation of pesticide productivity.

In another study, the contribution of fungicides and pruning to yield and quality improvement for a sample of 47 North Carolina apple orchards was analyzed (*1*). The main conclusions are: (1) quality improvement is an important component of fungicide productivity, (2) estimates of pesticide productivity are sensitive to model specification, and (3) fungicides were applied 2.24 times as much as the optimal level for risk-neutral producers. This suggests either that fungicides were overused or that farmers were willing to sacrifice a great deal of efficiency for the risk-reduction effects of fungicides.

Econometric Models

A recent development in the study of pesticide productivity is the separation of inputs into two categories—productive and protective (*7*). Productive inputs are regular inputs (such as fertilizers, labor, irrigation, and so forth) that are employed to expand output. Protective inputs are damage-control measures, such as pesticides, that are employed to reduce yield losses from natural causes. Specifically, the production function can be written as:

$$Q = aZ^b[G(X)]^c$$

where Q is output, Z represents a vector of productive inputs, X is a vector of protective inputs, a, b, and c are parameters. The damage-abatement function, $G(X)$, is defined as the proportion of the pest's destructive capacity eliminated by the application of a certain level of X. $G(X)$ falls in the range of (0, 1) with $G = 1$ denoting complete eradication of the destructive capacity and $G = 0$ denoting maximum destructive capacity.

In general, X should include not only damage control inputs but also state variables such as pest prevalence. The theory of incorporating state variables into the above production function was recently derived (*2*). Because of the lack of information on pest prevalence, X is represented by pesticides only in this study. Consequently, parameter estimates may suffer from specification bias. This problem has been encountered in all empirical studies of pesticide productivity.

As in past empirical studies, the parameter c is restricted to 1.0 (*1*, *5*). Three damage-abatement functions that have been utilized in recent empirical investigations are:

Weibull: $G(X) = 1 - \exp(-X^w)$

Logistic: $G(X) = 1/[1 + \exp(L_0 - L_1X)]$, and

Exponential: $G(X) = 1 - \exp(E_0 - E_1X)$

where w, L_0, L_1, E_0, and E_1 are parameters. These three damage- abatement functions are chosen because they allow the marginal productivity of protective inputs to decline at a faster rate than the log-log functional form.

Data

Potato yield was hypothesized to be affected by soil characteristics, weather, inputs, and production practices. Soil characteristics were obtained from the 1985 national resource inventory and the associated soils-5 survey. Weather data was provided by the National Oceanic and Atmospheric Administration. Field-level data on potato production practices and the subsequent yields came from the USDA's 1990 cropping practices survey and objective yield survey. The survey randomly samples fields in potato production for each stratum in the major producing states. (Some states have only one stratum and others have multiple strata).

In order to control yield variations due to regional characteristics, potato production in three PNW states (Idaho, Oregon, and Washington) were the focus of the study. An overwhelming portion of PNW potato production is irrigated and is intended for processed and fresh markets. Non-irrigated potato fields, as well as the production for purposes other than processed and fresh markets (such as seed), were excluded from the study.

USDA's 1990 cropping practices survey obtained complete input information for 498 samples in the three states. However, only 193 fields reported yield information. Further, only a few fields in Oregon reported yields and these fields were excluded from the study due to the small sample size from the state. Because many PNW potato farms are large, some survey fields are on the same farm and have identical or similar information on inputs used and output produced. Only one field was retained for all survey fields of a particular farm. The total number of fields in the final analysis is 81, 54 from Idaho and 27 from Washington.

Initially, the following variables were hypothesized to influence yields: (1) Seed: seeding rate, seed cost; (2) Fertilizer: the timing and quantity of nitrogen, phosphorus, and potash applications; (3) Pest control: the frequency of weed cultivation, the timing and quantity of pesticide applications; (4) Others: the purpose of the crop (processed or fresh market), farm program participation, crops planted during the previous 2 years.

Washington production has much higher potato yields than Idaho. A dummy variable was included to capture any yield differences between these two states that were not explained by other variables.

Estimation Procedures

While a random sample is drawn from each stratum, samples across strata have unequal chances of selection. (There are three strata in Idaho and one stratum in Washington). Each sample field was weighted by the number of acres it represents in the estimation. As discussed earlier, farms with multiple sample fields were limited to only one observation and this observation was weighted accordingly.

The three damage-abatement functions (Weibull, exponential, and logistic) are nonlinear in parameters, and nonlinear algorithms were employed in the estimation. Consequently, the value of the log-likelihood function instead of R^2 is reported. For comparison purpose, the log-log model is also estimated as a linear model.

In previous studies of pesticide productivity, pesticides have been measured either in value terms (*2*, *4*, *5*, *6*) or in quantity terms (*1*, *8*). In this study, both definitions of pesticides were employed. The empirical results suggest that defining pesticides in value terms (dollars per acre) produced more satisfactory results than defining them in quantity terms (pounds of active ingredients per acre).

This study only reports the results of measuring pesticides in value terms. This result is deemed reasonable because different pesticides have different efficacy, and efficacy should be reflected in pesticide prices. Suppose there are two different pesticide products that are effective in dealing with a particular pest at a particular infestation level. Their prices may differ, but their treatment costs per acre have to be similar; otherwise one product would have been priced out of the market. (Contact the authors for the results of defining the pesticide input in quantity terms.)

In the study, pesticides are defined as the sum of herbicides, insecticides, and fungicides. The reader should recognize that each of these pesticide categories targets a different pest species and therefore may have a different impact on overall estimates of pesticide productivity. The pesticide variable was classified according to the timing of application--before/at planting or after planting. The rationale is that after-planting applications of pesticides are likely to have higher productivity than before/at-planting applications. This is because farmers have a chance to scout the fields for actual pest infestation prior to pesticide application when pesticides are applied after planting.

There is a long list of practices, soil characteristics, and weather variables that were hypothesized to influence potato yields. Because the study focused on pesticide productivity, pesticide input was always retained, whereas other variables having a t-value of less than 1.0 were excluded from further estimation.

Results

Tables B-1 and B-2 list parameter estimates, t-values, and other summary statistics of the estimated input-output relationships. In table B-1, all pesticides are aggregated as a single variable whereas in table B-2, pesticides are separated into two variables--before/at-planting and after-planting pesticides. All continuous variables (i.e., yields measured in hundredweights per acre, nitrogen in pounds per acre, and Fahrenheit temperature) are transformed in logarithms. Two dummy variables are included in the models--Idaho and TFactor4. The dummy variable, Idaho, has a value of 1 for fields in Idaho. The T-Factor data have two values, 4 and 5, for soil erodibility. TFactor4 takes the value of 1 for those fields being located in a county with a county average of 4 for T-Factor.

Table B-1. PNW Potato input-output relationship: Pesticides aggregated as one input

	Log-log	Exponential	Logistic	Weibull
Constant	0.424	0.409	0.400	0.442
	(0.91) 1/	(0.89)	(0.88)	(0.96)
Nitrogen 2/	0.125	0.164	0.164	0.132
	(2.06)	(2.72)	(2.70)	(2.26)
TFactor4	-0.069	-0.080	-0.079	-0.064
	(1.46)	(1.74)	(1.77)	(1.43)
Temperat. 2/	1.149	1.167	1.169	1.204
June-Aug.	(8.07)	(8.53)	(9.05)	(9.09)
Idaho	-0.395	-0.410	-0.412	-0.402
	(7.96)	(8.15)	(8.91)	(8.43)
Pesticide	0.063			
	(1.83)			
w 3/				0.299
				(2.38)
L0 3/			0.666	
			(0.29)	
L1 3/			0.194	
			(0.88)	
E0 3/		0.018		
		(0.01)		
E1 3/		0.154		
		(1.09)		
Log-likelihood	29.92	32.11	32.09	30.51
Akaike AIC	-47.84	-50.22	-50.18	-49.02

1/ Numbers in parentheses are t-values. 2/ Yields, nitrogen, and temperature are in logarithms. 3/ The symbols correspond to those of the three damage-abatement functions.

All parameter estimates reported in tables B-1 and B-2 have signs consistent with *a priori* expectations. The log-log models are estimated as a linear model with a coefficient of determination of 0.73 for one pesticide variable and 0.74 for two pesticide variables. These coefficients of determination are considered very high for cross-section studies.

The parameter estimates and statistical significance produced by different models exhibit striking similarities and differences. The four models can be grouped according to their results: the exponential and logistic models are in one group, while the log-log and Weibull are in another.

The Akaike information criterion (AIC) can be used to compare the goodness-of-fit among the eight models; the four models for one pesticide variable and another four models for two pesticide inputs. The Akaike criterion is based on selecting the model which minimizes AIC = -2(log-likelihood) + 2(number of parameters) (*5*). In the case of treating pesticides as a single variable, the AIC indicates the ranking of exponential (-50.22), Logistic (-50.18), Weibull (-49.02), and log-log (-47.84). When there are two pesticide variables, the AIC implies the ranking of logistic (-54.80), exponential (-54.44), Weibull (-49.62), and log-log (-49.50). Apparently, separating pesticides according to the application timing improved the empirical results. This study focuses on table B-2 in result interpretation.

All four models suggest that after-planting pesticides have significant, positive effects on yields. Before/at-planting pesticides have insignificant effects on yields. The results are not unexpected because only after planting can farmers scout the fields for actual pest infestation and employ a va-

Table B-2. PNW Potato input-output relationship: Pesticides separated by application timing

	Log-log	Exponential	Logistic	Weibull
Constant	0.211	1.072	0.746	1.129
	(0.46) 1/	(2.20)	(1.40)	(2.63)
Nitrogen 2/	0.109	0.098	0.098	0.109
	(1.83)	(1.82)	(1.81)	(1.88)
TFactor4	-0.050	-0.067	-0.067	-0.050
	(1.10)	(1.61)	(1.61)	(1.16)
Temperat. 2/	1.269	1.192	1.187	1.268
June-Aug.	(9.65)	(9.56)	(9.44)	(10.0)
Idaho	-0.389	-0.353	-0.352	-0.389
	(8.03)	(7.52)	(7.54)	(8.38)
Before/at planting pesticides	0.0009			
	(0.38)			
■ 3/				-0.0018
				(0.39)
L0 3/			-4.301	
			(0.31)	
L1 3/			0.013	
			(0.06)	
E0 3/		-1.204		
		(0.64)		
E1 3/		0.0002		
		(0.08)		
After planting pesticides	0.0091			
	(2.35)			
■ 4/				0.017
				(2.54)
L0 4/			-1.144	
			(3.54)	
L1 4/			0.037	
			(2.37)	
E0 4/		-1.421		
		(5.38)		
E1 4/		0.031		
		(2.04)		
Log-likelihood	31.75	36.22	36.40	31.81
Akaike AIC	-49.50	-54.44	-54.80	-49.62

1/ Numbers in parentheses are t-values. 2/ Yields, nitrogen, and temperature are in logarithms. 3/ The symbols correspond to those of the three damage-abatement functions. 4/ For simplicity, identical symbols are used for before/at and after planting applications. In the estimation, before/at and after planting applications are represented by different parameters.

riety of means (such as split application, selection of application method (e.g., band vs. broadcast), spot treatment, and so forth) to improve pesticide efficacy.

Before/at-planting and after-planting pesticides are not completely substitutable due to biological, physical, and chemical constraints. The data do indicate some degrees of substitutability. A negative correlation (-0.31) between before/at-planting and after-planting pesticide expenditures is indicated in the data. Further, there are two cases exemplifying the substitutability of after-planting pesticide applications for before/at-planting applications.

Metribuzin and EPTC are two most commonly used herbicide active ingredients (ai) in Idaho and Washington. In Idaho, metribuzin can be applied before, at, or after planting, while EPTC can only be applied before planting. Both ai's can be applied to suppress annual grass and broadleaf weeds (*10*). Therefore, Idaho farmers can substitute after-planting metribuzin for before/at-planting metribuzin or for EPTC. In the case of insecticides, both phorate and ethoprop (mocap) are effective in suppressing wireworms. Ethoprop needs to be applied only before or at planting, while phorate can be applied after planting (*9*).

While all four models suggest significant, positive productivity of after-planting pesticides, they produce very different productivity estimates. The exponential and logistic models produce almost identical marginal productivity for after-planting pesticides, which are much higher than the marginal productivity generated by the log-log and Weibull models. At the mean value of $35/acre and at a farm price of $4.80 per cwt for processed potatoes, an additional dollar spent on post-planting pesticides (material cost only) generates $6.28, $5.86, $0.58, and $0.53 returns for the logistic, exponential, Weibull, and log-log models, respectively.

The log-log and Weibull models suggest that after-planting pesticides are overused, while the exponential and logistic models suggest they are likely underused. It should be emphasized that the costs of pesticide application are ignored in the study. Because the exponential and logistic models have better statistical fit than the log-log and Weibull models according to the AICs, the results seem to suggest that after-planting pesticides are underused.

The four models produce similar productivity estimates for nitrogen. The output elasticity for nitrogen is around 0.1, suggesting that a 1-percent increase in nitrogen use (averaged 240 pounds per acre in Idaho) will increase potato production by 0.1 percent (averaged around 300 cwt per acre in Idaho). Using a price of $18 per hundred pounds of nitrogen and $4.80 per cwt for potatoes, the return to the nitrogen *material cost* is almost 4 to 1, suggesting nitrogen is likely underused. Because the potato demand is fairly price inelastic, potato prices are volatile. Consequently, risk averse farmers may tend to underuse productive inputs such as nitrogen.

Conclusions

Pesticide productivity is an important piece of information in shaping policies and regulations related to agricultural pesticide use. Previous studies have suggested both overuse and underuse of agricultural pesticides. Differences in the findings have been attributed to model specification.

In the study, we estimated the pesticide productivity in potato production of the Pacific Northwest region in 1990. The results also indicate that estimates of pesticide productivity are highly sensitive to model selection. Issues in model selection involve the definition of pesticide input (value is deemed a better definition than quantity in this study) and the specification of damage abatement function.

The results further suggest that pesticide productivity may vary by the timing of applications. Whether or not the finding of time-varying pesticide productivity is unique to 1990 PNW potato production needs to be investigated. The factors causing variations in pesticide productivity by application timing should be studied.

Target pests and application requirements for the active ingredients frequently applied (e.g., EPTC, metribuzin, phorate, and others) need to be examined to ascertain the

Table B-3. Distribution of acre-treatments by pesticide category and application timing: 1990 potato production in Idaho and Washington.

	Application timing	
	Before/at	After
Herbicides		
Pounds of ai per acre	0.76	1.96
Dollars per acre	6.67	14.31
Insecticides		
Pounds of ai per acre	1.71	1.60
Dollars per acre	11.93	12.74
Fungicides		
Pounds of ai per acre	0	0.58
Dollars per acre	0	8.00

Table B-4. Percent of 1990 potato acres treated by pesticide category

	Idaho	Washington
Herbicides	93	92
Insecticides	81	95
Fungicides	39	74

degree of substitutability between pesticides applied at different times. Further, an understanding of the constraints which limit substitutability is needed.

The usefulness of the study can be improved by separating pesticides into three categories: herbicides, insecticides, and fungicides. This task was investigated without producing satisfactory results. As the number of damage-abatement measures (in terms of pesticide category and application timing) increase, the econometric model becomes highly nonlinear, resulting in difficulties in estimation. However, as shown in table B-3, both herbicides and insecticides were applied before/at and after planting. Fungicides were applied only after planting. Further, varying percentages of total potato acreage were treated with different pesticides (see table B-4). Because different pesticides are likely to have different productivity, research efforts should be devoted to estimating the productivity of the various categories of pesticides.

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The Relationship Between Cropping Patterns and Insecticide Use in Cotton Production

by

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Abstract: Recent policy initiatives aimed in part at reducing the use of agricultural chemicals have encouraged crop rotation as a substitute for insecticide use. In addition to potentially reducing environmental risk, substituting rotation for insecticide use can reduce farm-level variable costs. Utilizing USDA survey data, cotton farmers' per-acre insecticide expenditures are compared across different cropping patterns. In all instances, differences in insecticide expenditures between cropping patterns, though sometimes significant, are relatively small. Because farmers' cropping decisions are based upon expected profits, continuous cotton will be the preferred cropping pattern if opportunity costs of foregoing cotton production are great (i.e. the expected profit stream of noncontinuous cropping patterns is lower than for continuous cotton).

Keywords: Cotton, rotation, insecticide expenditures.

Introduction

Public concerns about the environmental impacts of chemical- intensive agriculture are increasing. A USDA study indicates groundwater supplies of approximately 46 percent of U.S. counties face potential contamination by pesticide or fertilizer use (*16*). Food safety, endangered species, farmworker safety, increased pest resistance, and destruction of beneficial insects are other issues associated with pesticide use. In response to these concerns, efforts are being made to encourage cropping practices that will decrease the amount of agricultural chemicals applied by farmers without sacrificing yields or income.

Crop rotation is suggested by integrated pest management specialists as one way to reduce farm-level demand for chemical inputs. The advantages of rotation can include increased soil moisture, maintaining soil fertility, more efficient utilization of resources, such as labor, and improved and more stable profits over time (*8*).

Another important benefit is controlling insects and disease. For example, rotating cotton with sorghum, corn, or small grains is useful in reducing pests such as boll weevil, bollworm, tobacco budworm, pink bollworm and rootrot (*9*). In the case of corn, rotating to another crop, such as soybeans, can significantly reduce corn rootworm infestation, therefore requiring less insecticide use (*14*).

Given that entomologists have shown a linkage between infestations of certain pests and previous crop, the purpose of this paper is to assess whether cotton producers who rotate crops have lower pesticide expenditures than those who grow continuous cotton.

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Policies Affecting Crop Rotation

In the past, commodity programs have been viewed as a constraint to planting flexibility in that participants are "forced" to plant program crops. Planting inflexibilities arise from government programs that require farmers to plant program crops in order to maintain a base history and to receive deficiency payments (*12*).

Several recent U.S. policies encourage more crop rotation. A major provision of the 1990 farm legislation makes 15 percent of a farm's base acreage ineligible for deficiency payments and allows other crops to be planted on it. Beginning in 1991, farmers could plant an additional 10 percent of their crop acreage base to other specific crops without losing any base. For upland cotton, USDA data from 1992 indicate that nearly 319,000 acres of this flexible (flex) acreage was planted to other crops, while more than 452,000 acres of other program crops were flexed into cotton. Total acreage planted to cotton in 1992 was approximately 13.4 million. A similar pattern emerged in 1991, the first year the flex provision was available.

The Integrated Farm Management Program Option (IFM), established by the 1990 Farm Act, offers additional flexibility. Under IFM, farmers are encouraged to adopt soil and water conserving practices by converting land to resource-conserving crops while protecting their government payments. The Water Quality Incentive Program is another USDA program which encourages farmers to change cropping sequences when the potential for ground or surface water contamination will be reduced.

Economic Considerations

In addition to reducing potential environmental impacts, lowered agricultural chemical use through crop rotation can provide several economic benefits for farmers. Fore-

most among these is reduced production costs. By substituting rotations for pesticides, farmers may be able to reduce the number of treatments per season, as well as the amount of pesticide applied in each application. For example, evidence from the Palouse region of Washington indicates that fertilizer and pesticide costs associated with conventional wheat cropping practices were nearly five times higher than an experimental, low-input legume-based rotation (*10*).

However, the cotton producer needs to weigh this reduced cost against the opportunity cost for first-year cotton. If there is a large profit penalty for rotation to a noncotton crop, then the producer will not rotate unless pesticide and/or other input savings are greater than the opportunity cost of first-year cotton. Hence, an important determinant of a producer's cropping pattern is the expected price and yield of the alternative crop relative to cotton.

Economic modeling efforts to determine the key factors influencing insecticide use have utilized a variety of approaches (*3,2,13,15*). Typically, insecticide demand is a function of own price, price of chemical and nonchemical substitutes (e.g. pest scouting, planting pest-resistant varieties, cultural practices, and so forth), and expected price of the output. Several studies have pointed out the importance of also including pest infestation levels, risk attitudes, commodity programs, weather/climate, regional pest eradication programs, and pest resistance (*1,4,11*).

This paper, while recognizing the possible influence of a number of these factors on insecticide use, narrowly focuses on the linkage between crop rotations and insecticide use. Specifically, per acre insecticide expenditures are compared for continuous cotton acreage versus rotated cotton acreage in the major producing states.

The analysis presented here is highly restrictive in the sense that neither a model of land rotation nor insecticide demand is estimated. However, the field-level data used in this paper can be used to indicate the association between previous crop and current year's insecticide use, whereas data for a comprehensive insecticide-rotation model were not available. Furthermore, by examining data on a state-by-state basis, the possibility of mis-specification is reduced because many of the variables, such as pest infestation, input and output prices, production practices, and weather/climate, are more similar within states than between states.

Data

The data used in this study were drawn from USDA's 1991 cropping practices survey of the six major cotton producing states. A random sample totalling 1,136 cotton fields was selected. The study looks only at upland cotton production.

Observations contained information on cropping patterns and pesticide and other-input use. The data indicate that more than 66 percent of upland cotton acreage in these states was treated with an insecticide in 1991. Methyl parathion, lambdacyhalothrin, and dicrotophos accounted for the highest percentage of insecticide-treated acres. Table C-1 indicates the percentage of acres treated with the most commonly used insecticides, the average number of applications per crop year, and the average number of pounds applied per application. Table C-2 presents the percentage of acres within each state treated with a specific insecticide.

In Arizona, 95 percent of the acreage was treated with an insecticide. This proportion is similar to the other states, excluding Texas. However, Arizona's annual per-acre rate

Table C-1. Cotton insecticide use, major producing states/1, 1991

Active ingredient	Acres treated (%)	Number of treatments (Per year)	Application rate (lbs./acre)	Total applied (M/lbs.)
All insecticides	67			
Acephate	10	1.5	0.35	583
Aldicarb	10	1.0	0.54	569
Azinphos-methyl	7	1.4	0.24	262
Chlorpyrifos	5	2.1	0.58	718
Cyfluthrin	8	2.0	0.03	61
Cypermethrin	11	1.3	0.05	72
Dicofol	5	1.0	0.73	423
Dicrotophos	13	1.3	0.24	440
Dimethoate	7	1.4	0.24	236
Esfenvalerate	11	1.6	0.03	57
Ethyl parathion	3	1.1	0.64	195
Lambdacyhalothrin	14	1.8	0.02	70
Methomyl	5	1.5	0.20	171
Methyl parathion	14	2.1	0.47	1,528
Oxamyl	5	1.4	0.21	157
Phorate	2	1.3	0.71	193
Thiodicarb	3	1.6	0.38	226
Tralomethrin	7	1.8	0.01	10

1--States included: AZ, AR, CA, LA, MS, and TX.

Source: "Agricultural Chemical Usage 1991 Field Crops Summary," NASS and ERS, USDA, March 1992.

Table C-2. Acres treated with cotton insecticide use, major producing states, 1991

Chemical	AZ	AR	CA	LA	MS	TX
Acres planted (1,000)	360	990	940	800	1,190	6,380
			Percent of acres treated			
All insecticides	95	56	86	88	91	56
Active ingredient						
Acephate	49		5		19	7
Aldicarb	17	11	10	28	13	7
Azinphos-methyl	14					7
Chlorpyrifos	73					3
Cyfluthrin				21	20	6
Cypermethrin	17	15			13	10
Dicofol			57			
Dicrotofos				18	20	15
Dimethoate	21	13			7	5
Esfenvalerate	21	18			20	8
Ethyl parathion						4
Lambdacyhalothrin	28			28		13
Methomyl	30					7
Methyl parathion	42	10		34	50	5
Oxamyl					7	6
Phorate			9			
Profenofos			4			
Thiodicarb	17'					3
Tralomethrin	14				17	5

Source: "Agricultural Chemical Usage 1991 Field Crops Summary," NASS and ERS, USDA, March 1992.

of more than 4 pounds of active ingredient per treated acre was significantly higher than the 1-pound average in the rest of the survey states and reflects a higher number of applications per year. This is due to increased pest pressure associated with the unique agro-climatic characteristics of production in the state and severe whitefly infestations during the survey year (*5*). The lower percentage of insecticide-treated acreage in Texas reflects, in part, lower pest pressure in the western part of the state.

Per-acre insecticide expenditures were developed by multiplying the reported per-acre application rate by the national average price of a pound of active ingredient (*7*). Similar measures were employed by Carlson (*4*) in 1977 and Burrows (*3*) in 1983. This differs from most previous studies that use the number of pounds of active ingredient to compare pesticide use (*6,14*).

The advantage of the per-acre expenditure method is that it reflects chemical attributes such as efficacy, thus providing a more accurate portrait of the substitutability of different classes of insecticides. For example, a pyrethroid priced at $100 per pound of active ingredient and applied at the rate of 0.1 pound per acre may provide the same level of control as a carbamate priced at $10 per pound of active ingredient with an application rate of 1 pound per acre. In both cases, the per-acre chemical cost is $10.

An analysis of cropping patterns reveals that continuous cotton is widely practiced in the six survey states (table C-3). Seventy-two percent of all acreage was planted to cotton the previous year, while 61 percent was planted to cotton the 2 previous years. Rotations with corn and soybeans are popular in Arkansas and Louisiana. Sorghum is commonly rotated with cotton in East Texas. As mentioned above, these rotations can be effective in controlling several cotton pests, including boll weevil.

In California, farmers' rotations include cotton-fallow (16 percent), cotton-alfalfa (11 percent), and cotton-vegetable (7 percent). In Arizona, nearly 91 percent of the cotton acreage was planted to cotton the previous year, while 5 percent was fallow. For the six survey states, 6 percent of cotton acreage was fallow the preceding year.

Table C-3. Previous crop on field producing cotton, major producing states, 1991

Previous crop	AZ	AR	CA	LA	MS	East TX	West TX	Area
Acres planted (1,000)	360	990	940	800	1,190	1,380	5,000	10,660
	Percent							
Cotton	91	81	58	90	83	37	75	72
Alfalfa	3	nr	11	nr	nr	1	0	1
Corn	nr	nr	2	3	nr	7	6	4
Fallow	5	1	16	nr	8	1	6	6
Sorghum	nr	nr	nr	nr	nr	46	3	7
Soybean	nr	17	nr	7	7	3	1	4
Vegetable	nr	nr	7	nr	1	1	nr	1
Wheat	1	nr	2	nr	nr	1	7	4
Other	nr	1	4	nr	1	3	2	1
Total	100	100	100	100	100	100	100	100

nr=None reported.

Results

The method of analysis used in this study was a t-test, to compare insecticide expenditure by previous crop. The hypothesis tested was that the expenditure means were not statistically different on fields where the previous crop was cotton, compared to fields where cotton was not planted the prior cropping season.[2] In California and the two regions in Texas, a large enough number of observations permitted the comparison of several different types of rotation. These rotations were defined in consultation with cotton entomologists in each of the respective states. Expenditure means and results of the hypotheses tests are presented in tables C-4 and C-5.

With the exception of Arizona, mean per-acre insecticide expenditures range from $5-$21 per acre. Arizona's $57-per-acre insecticide expenditure reflects in part the severe whitefly infestation during the survey year. The average per-acre insecticide expenditure for the six surveyed states was slightly more than $11 per acre. Excluding West Texas, which uses little insecticides and accounts for half the acreage in the study, mean insecticide expenditures were nearly $16 per acre.

Across states, the results of the effect of rotations on insecticide expenditures are mixed. In Arizona, Arkansas, Mississippi, and East Texas, per-acre insecticide expenditures were lower on fields that were planted to crops-other-than-cotton the preceding year. In East Texas, the means were different at the 5-percent level of significance. In Arkansas and Mississippi, the means differed at the 10-percent significance level. For California and West Texas, insecticide expenditure means were higher on rotated acreage, but the differences were not statistically significant at the 10-percent level of significance.

Results of the tests for the expanded rotations were also mixed. In California, fields which were planted to alfalfa the previous year showed mean insecticide expenditures to be more than $7 higher than those not rotated. This significant difference reflects the use of profenofos, which is used to control lygus. Lygus infestation on cotton is a problem when alfalfa was the previous crop planted to the field. Compared to continuous cotton, insecticide expenditures were lower when the field was fallow the previous year. Mean per-acre insecticide expenditures on cotton and all other previous crops were nearly identical in California.

Results from East Texas indicate that rotation leads to lower per-acre insecticide expenditures. Where the previous crop was sorghum, mean expenditures were reduced more than $6 per acre, which is significant at the 5-percent level. For all other previous crops, the mean was lower, but the difference was not statistically significant.

2 Although data were gathered for Louisiana, the small sample size and widespread practice of continuous cotton limited the number of valid observations of farmers whose previous crop was not cotton. For this reason, statistical analysis was not performed.

Table C-4. Statistical results of per-acre insecticide expenditures, by state and rotation, 1991

State	Number fields	Mean exp. trtd. acre	Acres rotated	Mean exp. planted acres: Previous crop		T-stat
				Cotton	Other	
	n	Dollars	Percent			
AZ	76	57.26 (4.55)	9	58.03 (4.86)	49.72 (12.96)	0.53
AR	92	6.63 (1.00)	19	7.20 (1.19)	4.14 (1.43)	1.64**
CA	181	11.61 (0.73)	42	11.49 (0.91)	12.10 (1.24)	-0.41
MS	132	21.13 (1.37)	17	22.50 (1.55)	16.12 (3.51)	1.69**
E. TX	69	8.15 (1.24)	63	11.27 (2.52)	6.03 (1.33)	2.00*
W. TX	413	5.01 (0.38)	25	4.85 (0.45)	5.55 (0.75)	-0.80

* Significant at the 5-percent level.
** Significant at the 10-percent level.
Note: Figures in parentheses represent standard error of the mean.

Table C-5. Results of expanded rotations, by state, 1991

Previous crop	n	Percent	Mean exp. planted acres (Dollars)	T-stat
California:				
Cotton	105	58	11.48 (0.91)	
Alfalfa	20	11	18.61 (2.21)	-2.98**
Fallow	28	16	8.03 (1.82)	1.70**
Other	28	16	11.41 (2.00)	0.03
East Texas:				
Cotton	26	39	11.27 (2.52)	
Sorghum	32	52	5.18 (1.55)	2.05*
Other	9	9	7.87 (3.10)	0.69
West Texas:				
Cotton	309	75	4.85 (0.45)	
Fallow	53	13	5.12 (0.96)	-0.25
Corn	26	6	6.14 (1.29)	-0.81
Other	25	6	5.84 (1.99)	-0.50

* Significant at the 5-percent level.
** Significant at the 10-percent level.
Note: Figures in parentheses represent standard error of the mean.

In West Texas, the mean insecticide expenditures for all identified rotations were higher than on continuous cotton. The differences, however, were not statistically significant.

Conclusions

The effects of previous crop on current insecticide expenditure on cotton are mixed. In East Texas, where a cotton-sorghum rotation has provided increased insect control, fields previously planted to sorghum have lower average insecticide expenditures per acre than fields in continuous cotton. Rotation is also correlated with reduced insecticide expenditures in Arkansas, Mississippi, and for a cotton-alfalfa rotation in California.

On the other hand, per-acre insecticide expenditures are higher on rotated fields in West Texas and for a cotton-fallow rotation in California.

In all instances, differences in insecticide expenditures between cropping patterns, though sometimes significant, are relatively small. Hence, continuous cotton will be the preferred cropping pattern if opportunity costs of first-year cotton are great (i.e. the expected profit stream of noncontinuous cropping patterns is lower than for continuous cotton).

These results suggest that any economic benefits accruing to cotton growers by substituting rotations for insecticides are slight. An important implication of this is that rotations generally do not appear to significantly affect the number of treatments or intensity of applications of pesticides.[3] Consequently, given current production practices of cotton producers, rotating cotton is not likely to greatly reduce potential environmental risks of insecticide use in cotton.

Recommendations for Further Study

The results presented above are not definitive regarding the effect of crop-rotation on insecticide use in cotton. To fully understand this relationship, there is a need for a more complete model of crop rotation decisions and cotton insecticide demand. These efforts would require additional data on target pests, expected profits under various cropping scenarios, producer risk preferences, and so forth.

Another issue for further study is the effect of USDA cotton commodity program participation on insecticide use and crop rotation, either through output price enhancement of the commodity or reduced flex acreage through base-acreage-use rules. In terms of the output price issue, some argue that prices set artificially high encourage more intensive use of inputs than would occur under market conditions. Regarding the base use issue, the base acreage provisions of commodity programs are seen by some as preventing farmers from adopting more sustainable production practices.

Finally, an examination of rotation's effect on classes of insecticide used (e.g. pyrethroids versus carbamates), rather than expenditures, may offer insights into rotations that use more environmentally benign chemicals.

3 A logistic regression investigating production practices showed no significant differences in the annual number of insecticide treatments between continuous and noncontinuous cotton.

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Appendix table 1--U.S. fertilizer imports: Declared value of selected materials

Material	Fertilizer year 1990/91	Fertilizer year 1991/92	July-November 1991	July-November 1992
	$ million			
Nitrogen:				
Anhydrous ammonia	297	307	124	113
Aqua ammonia	1	1	*	*
Urea	210	176	71	67
Ammonium nitrate	44	52	21	19
Ammonium sulfate	24	27	9	8
Sodium nitrate	15	20	6	8
Calcium nitrate	6	11	5	3
Nitrogen solutions	19	16	7	3
Other	8	12	6	3
Total 1/	624	622	249	224
Phosphate:				
Ammonium phosphates	1	5	1	1
Crude phosphates	22	37	10	19
Phosphoric acid	*	*	*	*
Normal and triple superphosphate	*	*	*	*
Other	1	*	*	*
Total 1/	24	42	11	20
Potash:				
Potassium chloride	519	550	202	206
Potassium sulfate	10	11	4	3
Potassium nitrate 2/	13	12	1	5
Other	28	20	9	10
Total 1/	570	593	216	224
Mixed fertilizers	28	31	8	10
Total 1/	1,247	1,288	484	478

na = Not available. * = Less than $500,000.

1/ Totals may not add due to rounding. 2/ Includes potassium sodium nitrate.

Source: (7).

Appendix table 2--Plant nutrient use by State for years ending June 30 1/

State/ region	1991			1992		
	Nitrogen	Phosphate	Potash	Nitrogen	Phosphate	Potash
	1,000 nutrient tons					
Maine	11	10	10	13	10	9
New Hampshire	2	1	1	3	1	2
Vermont	5	4	6	6	4	6
Massachusetts	12	5	7	13	6	8
Rhode Island	2	1	1	2	1	1
Connecticut	4	2	[illegible]	5	2	3
New York	79	54	74	95	73	95
New Jersey	31	17	21	23	12	16
Pennsylvania	73	52	62	71	55	60
Delaware	21	7	24	22	8	17
Maryland	59	36	53	75	36	49
NORTHEAST	299	188	262	328	208	267
Michigan	265	115	224	257	111	228
Wisconsin	243	112	266	236	115	271
Minnesota	621	252	342	626	242	310
LAKE STATES	1,128	479	832	1,119	468	809
Ohio	346	138	268	331	140	251
Indiana	563	242	410	584	250	395
Illinois	1,006	392	638	951	391	639
Iowa	957	322	485	969	309	452
Missouri	408	169	244	443	178	250
CORN BELT	3,280	1,262	2,044	3,279	1,269	1,987
North Dakota	390	178	34	383	163	28
South Dakota	197	86	24	169	84	19
Nebraska	752	151	35	755	173	35
Kansas	640	168	41	647	158	40
NORTHERN PLAINS	1,978	583	134	1,954	577	123
Virginia	99	72	100	119	80	112
West Virginia	7	8	7	10	10	[illegible]
North Carolina	204	102	182	218	109	196
Kentucky	202	109	137	208	111	139
Tennessee	149	92	113	164	100	127
APPALACHIA	662	384	539	718	409	584
South Carolina	75	32	64	78	35	70
Georgia 2/	192	105	150	203	116	163
Florida	237	95	239	248	95	258
Alabama	123	49	64	125	49	66
SOUTHEAST	627	281	517	655	295	556
Mississippi	198	46	74	205	62	101
Arkansas	251	65	93	277	67	105
Louisiana	159	43	61	192	50	73
DELTA STATES	609	154	229	674	180	280
Oklahoma	345	80	33	343	77	33
Texas	878	254	116	849	211	113
SOUTHERN PLAINS	1,223	334	150	1,192	288	146
Montana	97	61	14	123	65	14
Idaho	152	74	32	163	82	19
Wyoming	81	18	2	67	13	2
Colorado	165	48	20	130	49	14
New Mexico	36	13	[illegible]	33	13	6
Arizona	75	28	2	79	27	1
Utah	20	11	2	20	12	3
Nevada	4	2	1	4	3	1
MOUNTAIN	628	255	80	619	263	60
Washington	169	51	35	191	53	36
Oregon	130	43	28	149	44	30
California	519	170	118	490	141	135
PACIFIC	817	264	181	829	237	201
48 States and D.C.	11,252	4,185	4,969	11,365	4,194	5,012
Alaska	3	1	0	3	1	1
Hawaii	18	9	19	18	9	18
Puerto Rico	14	5	13	15	6	14
U.S. TOTAL	11,287	4,200	5,001	11,400	4,210	5,045

1/ Totals may not add due to rounding. 2/ Data is estimated.

Source: (3).

Appendix table 3--Fertilizer use on corn for grain, 1992

State	Acres planted 1/	Fields in survey	Acres receiving: Any ferti-lizer	N	P2O5	K2O	Application rates: N	P2O5	K2O	Proportion fertilized: At or before seeding	After seeding	Both
	1,000	No.	----------Percent--------				---Pounds/acre-----			------Percent-------		
Illinois	11,200	723	99	99	85	84	155	77	105	83	2	15
Indiana	6,100	495	98	97	89	84	143	66	107	53	2	45
Iowa	13,400	595	97	96	77	73	118	57	69	83	5	11
Michigan	2,700	318	97	96	89	85	119	52	87	43	5	52
Minnesota	7,200	524	97	97	87	[illegible]	110	48	64	81	1	18
Missouri	2,450	311	98	96	75	77	138	52	70	78	7	15
Nebraska	8,300	558	98	98	73	29	136	37	19	59	5	35
Non-irrigated	2,700	192	95	95	56	25	94	41	19	78	10	11
Irrigated	5,600	366	99	99	81	30	155	35	19	51	3	46
Ohio	3,800	401	100	100	92	88	149	69	96	37	2	61
South Dakota	3,800	301	85	84	72	29	78	38	19	88	4	8
Wisconsin	3,900	368	99	99	95	95	86	44	62	73	2	25
Area	62,850	4,594	97	97	82	72	127	57	79	72	3	25

1/ Preliminary.

Appendix table 4--Fertilizer use on cotton, 1992

State	Acres planted 1/	Fields in survey	Acres receiving: Any ferti-lizer	N	P2O5	K2O	Application rates: N	P2O5	K2O	Proportion fertilized: At or before seeding	After seeding	Both
	1,000	No.	----------Percent---------				----Pounds/acre----			------Percent-------		
Arizona	320	84	99	94	43	9	132	45 *	24 **	7	71	22
Arkansas	980	134	98	98	64	74	88	44	66	29	12	59
California	1000	188	97	97	32	5	131	86	42 **	29	36	35
Louisiana	900	83	99	98	57	59	78	44	75	34	27	39
Mississippi	1350	164	100	100	41	73	112	57	98	20	17	63
Texas	5650	506	65	65	48	27	66	44	20	74	14	11
Area	10,200	1,159	80	80	48	37	88	48	57	48	21	32

* = CV greater than 10 percent. ** = CV greater than 20 percent.

1/ Preliminary.

Appendix table 5--Fertilizer use on rice, 1992

State	Acres planted 1/	Fields in survey	Acres receiving: Any ferti-lizer	N	P2O5	K2O	Application rates: N	P2O5	K2O	Proportion fertilized: At or before seeding	After seeding	Both
	1,000	No.	----------Percent---------				----Pounds/acre----			------Percent-------		
Arkansas	1,350	233	98	98	12	17	143	40	59	9	63	28
Louisiana	600	145	99	99	83	82	112	45	46	2	64	34
Area	1,950	378	98	98	34	37	134	44	50	7	63	30

1/ Preliminary.

Appendix table 6--Fertilizer use on soybeans, 1992

State	Acres planted 1/	Fields in survey	Acres receiving: Any fertilizer	Acres receiving: N	Acres receiving: P2O5	Acres receiving: K2O	Application rates: N	Application rates: P2O5	Application rates: K2O	Proportion fertilized: At or before seeding	Proportion fertilized: After seeding	Proportion fertilized: Both
	1,000	No.	Percent				Pounds/acre			Percent		
Northern:												
Illinois	9,500	552	27	10	19	26	20	53	86	99	1	0
Indiana	4,550	373	42	21	31	39	12 *	39	84	94	6	0
Iowa	8,100	452	16	10	12	14	24 *	57	72	86	9	4
Minnesota	5,500	322	20	15	16	14	28 **	42 *	47	94	6	0
Missouri	4,300	348	24	10	20	22	23 **	43	59	95	2	2
Nebraska	2,500	257	21	20	18	8	17 *	31	10 **	85	11	4
Ohio	3,700	305	45	15	29	44	15 *	47	89	97	3	0
Sub-area	38,150	2,609	27	13	19	23	20	46	76	95	4	1
Southern:												
Arkansas	3,200	341	35	12	31	31	31 *	48	71	94	5	1
Georgia	650	146	58	40	54	57	18	43	76	93	7	0
Kentucky	1,180	183	46	37	44	42	44 *	74	87	96	0	4
Louisiana	1,200	222	18	4	17	18	20 **	42	54	100	0	0
Mississippi	1,850	285	18	[illegible]	17	18	17 *	44	65	100	0	0
North Carolina	1,400	179	68	54	63	67	20	35	81	96	2	2
Tennessee	1,000	179	56	27	53	56	28 *	60	69	100	0	0
Sub-area	10,480	1,535	39	22	36	37	27	49	74	97	2	1
Area	48,630	4,144	29	15	23	26	22	47	76	95	4	1

* = CV greater than 10 percent. ** = CV greater than 20 percent.

1/ Preliminary.

Appendix table 7--Fertilizer use on wheat, 1992

State	Acres 1/ 2/	Fields in survey	Acres receiving: Any fertilizer	Acres receiving: N	Acres receiving: P2O5	Acres receiving: K2O	Application rates: N	Application rates: P2O5	Application rates: K2O	Proportion fertilized: At or before seeding	Proportion fertilized: After seeding	Proportion fertilized: Both
	1,000	No.	Percent				Pounds/acre			Percent		
Winter wheat:												
Arkansas	900	67	100	100	36	36	101	44	58	1	61	37
Colorado	2,300	90	63	63	15	6	39	16 *	10 **	79	10	11
Idaho	800	92	91	91	51	7	93	35 *	28 **	37	29	34
Illinois	1,100	72	98	98	86	71	86	73	85	8	14	78
Indiana	450	62	98	98	83	81	88	62	67	17	13	70
Kansas	10,900	253	87	87	50	8	58	33	32 *	66	7	28
Missouri	1,350	71	96	96	82	82	77	49	54	28	24	48
Montana	2,250	96	81	81	78	19	35	24	19 **	82	2	16
Nebraska	1,950	99	77	77	38	7	47	29	13 **	69	12	19
Ohio	1,140	67	100	100	94	91	89	63	65	15	13	72
Oklahoma	6,000	161	95	94	46	#	73	33	21 **	48	10	42
Oregon	850	96	97	97	19	10	63	34 *	25 *	73	11	16
South Dakota	1,200	56	45	45	37	2	35 *	31 *	#	65	18	18
Texas	3,800	173	69	69	31	6	77	41	14 **	69	11	20
Washington	2,000	137	97	97	40	7	75	28 *	17 **	83	1	15
Area	36,990	1,592	85	85	48	17	66	38	48	57	11	32
Spring wheat:												
Minnesota	2,800	67	99	96	90	66	86	34	39 *	97	0	3
Montana	2,650	69	59	58	[illegible]	9	28 *	24	11 **	95	2	2
North Dakota	9,200	116	86	85	76	17	56	28	14 *	100	0	0
South Dakota	2,700	57	74	74	61	5	43	24	#	100	0	0
Area	17,350	309	82	81	72	22	57	29	26 *	99	0	1
Durum wheat:												
North Dakota	2,200	123	73	73	60	7	51	26	12 **	100	0	0
All wheat 3/												
Arkansas	900	67	100	100	36	36	101	44	58	1	61	37
Colorado	2,300	90	63	63	15	6	39	16 *	10 **	79	10	11
Idaho	800	92	91	91	51	7	93	35 *	28 **	37	29	34
Illinois	1,100	72	98	98	86	71	86	73	85	8	14	78
Indiana	450	62	98	98	83	81	88	62	67	17	13	70
Kansas	10,900	253	87	87	50	8	58	33	32 *	66	7	28
Minnesota	2,800	67	99	96	90	66	86	34	39 *	97	0	3
Missouri	1,350	71	96	96	82	82	77	49	54	28	24	48
Montana	4,900	165	69	68	62	13	32	24	16 **	88	2	10
Nebraska	1,950	99	77	77	38	7	47	29	13 **	69	12	19
North Dakota	11,400	239	84	83	73	15	55	28	14 *	100	0	0
Ohio	1,140	67	100	100	94	91	89	63	65	15	13	72
Oklahoma	6,000	161	95	94	46	#	73	33	21 **	48	10	42
Oregon	850	96	97	97	19	10	63	34 *	25 *	73	11	16
South Dakota	3,900	113	65	65	54	4	42	26	#	92	4	4
Texas	3,800	173	69	69	31	6	77	41	14 **	69	11	20
Washington	2,000	137	97	97	40	7	75	28 *	17 **	83	1	15
Area	56,540	2,024	84	83	56	18	63	34	39	71	7	21

* = CV greater than 10 percent. ** = CV greater than 20 percent.
\# = Insufficient data.

1/ Acres are harvested for winter wheat and planted for all other crops. 2/ Preliminary. 3/ Does not include winter wheat in MN, and ND; spring wheat in CO, and WA; or durum wheat in MN, MT, and SD.

Appendix table 8--Projected world supply-demand balances of plant nutrients for years ending June 30

World regions	Nitrogen		Phosphate		Potash	
	1992	1997	1992	1997	1992	1997
	Million metric tons					
Africa:						
Supply	2.02	2.34	5.03	5.58	0.00	0.00
Demand	2.10	2.70	1.15	1.40	0.50	0.60
Balance	-0.08	-0.36	3.88	4.18	-0.50	-0.60
America:						
Supply	15.92	16.51	11.69	12.03	10.40	11.67
Demand	15.10	16.00	6.51	6.92	6.87	7.45
Balance	0.82	0.51	5.18	5.11	3.53	4.21
North America--						
Supply	11.21	11.52	9.84	10.11	10.29	11.42
Demand	11.50	11.50	4.35	4.30	4.99	5.10
Balance	-0.29	0.02	5.49	5.81	5.30	6.32
Central America--						
Supply	3.28	3.38	0.62	0.61	0.00	0.00
Demand	1.85	2.20	0.50	0.67	0.30	0.40
Balance	1.43	1.17	0.12	-0.06	-0.30	-0.40
South America--						
Supply	1.44	1.61	1.22	1.31	0.11	0.24
Demand	1.75	2.30	1.66	1.95	1.58	1.95
Balance	-0.31	-0.69	-0.44	-0.64	-1.47	-1.71
Asia:						
Supply	30.02	37.04	8.27	9.57	2.13	2.31
Demand	37.50	43.00	14.19	16.09	5.55	6.19
Balance	-7.48	-5.96	-5.92	-6.52	-3.42	-3.88
West Asia--						
Supply	2.97	5.47	1.39	1.83	2.09	2.21
Demand	2.60	3.10	1.64	1.98	0.15	0.19
Balance	0.37	2.37	-0.25	-0.15	1.94	2.02
South Asia--						
Supply	7.97	10.33	1.02	1.17	0.00	0.00
Demand	10.00	12.50	3.75	4.71	1.55	1.80
Balance	-2.04	-2.17	-2.73	-3.54	-1.55	-1.80
East Asia--						
Supply	19.08	21.24	5.85	6.57	0.04	0.10
Demand	24.90	27.40	8.80	9.40	3.85	4.20
Balance	-5.82	-6.16	-2.95	-2.83	-3.81	-4.10
Europe:						
Supply	13.95	14.49	5.20	4.91	7.13	6.40
Demand	12.90	12.40	4.92	5.12	5.40	5.80
Balance	1.05	2.09	0.28	-0.21	1.73	0.60
East Europe--						
Supply	4.96	5.39	1.85	1.86	0.00	0.00
Demand	2.70	3.00	0.82	1.23	0.60	1.20
Balance	2.26	2.39	1.03	0.63	-0.60	-1.20
West Europe--						
Supply	8.98	9.10	3.35	3.05	7.13	6.40
Demand	10.20	9.40	4.10	3.89	4.80	4.60
Balance	-1.22	-0.30	-0.75	-0.84	2.33	1.80
Former USSR:						
Supply	14.90	14.38	6.75	6.80	7.82	8.91
Demand	8.10	7.80	7.00	6.80	4.90	5.20
Balance	6.80	6.58	-0.25	0.00	2.92	3.71
Oceania:						
Supply	0.40	0.40	0.66	0.66	0.00	0.00
Demand	0.53	0.68	0.82	1.07	0.25	0.27
Balance	-0.13	-0.28	-0.16	-0.42	-0.25	-0.27
WORLD TOTAL:						
Supply	77.20	85.16	37.58	39.54	27.48	29.28
Demand	76.23	82.58	34.59	37.40	23.47	25.51
Balance	0.97	2.58	2.99	2.14	4.01	3.77

Source: (4).

Appendix table 9-Tillage systems used in corn production, 1992

Category	IL	IN	IA	MI	MN	MO	NE 1/	NE 2/	OH	SD	WI	Area
Planted acres (1,000) 3/	11,200	6,100	13,400	2,700	7,200	2,450	2,700	5,600	3,800	3,800	3,900	62,850
	Percent of acres 4/											
Tillage system:												
Conv/w mbd plow 5/	5	8	7	25	19	6	3	2	31	11	40	12
Conv/wo mbd plow 6/	54	54	47	46	58	60	36	41	34	52	45	49
Mulch-till 7/	22	25	33	18	19	16	37	31	12	29	10	25
Ridge-till 8/	id	id	1	nr	3	nr	3	16	nr	1	nr	2
No-till 9/	18	13	11	10	1	19	21	11	23	7	5	12
Residue remaining after planting:	Percent of soil surface covered											
Conv/w mbd plow	2	2	3	2	2	3	3	2	2	3	2	2
Conv/wo mbd plow	17	16	19	17	16	14	18	17	15	18	17	17
Mulch-till	37	38	37	41	36	39	42	41	38	38	38	38
Ridge-till	id	id	37	nr	26	nr	46	52	nr	25	nr	45
No-till	61	64	64	74	58	65	60	67	66	69	80	65
Average	29	26	29	23	18	27	36	35	26	26	16	27
	Number											
Hours per acre:												
Conv/w mbd plow	.6	.6	.6	.6	.7	.6	.8	.6	.6	.5	.8	.6
Conv/wo mbd plow	.3	.4	.3	.4	.4	.4	.4	.3	.4	.3	.6	.4
Mulch-till	.2	.3	.2	.3	.3	.3	.3	.3	.4	.2	.5	.3
Ridge-till	id	id	.1	nr	.1	nr	.2	.2	nr	.1	nr	.2
No-till	.1	.1	.1	.2	.1	.1	.1	.2	.2	.1	.2	.1
Average	.3	.3	.3	.4	.4	.4	.3	.3	.4	.3	.6	.3
Times over field:												
Conv/w mbd plow	3.8	3.3	3.7	3.4	3.8	3.4	3.8	2.7	3.2	3.5	3.7	3.6
Conv/wo mbd plow	3.1	3.1	2.8	3.4	3.2	3.6	2.9	3.3	3.3	3.0	3.4	3.1
Mulch-till	2.4	2.4	2.2	2.5	2.5	2.6	2.2	2.5	2.6	2.4	3.1	2.4
Ridge-till	id	id	1.0	nr	1.0	nr	1.3	1.7	nr	1.0	nr	1.5
No-till	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.6	1.0	1.0	1.0	1.1
Average	2.6	2.7	2.4	3.0	3.1	2.9	2.2	2.6	2.7	2.7	3.3	2.7

id = Insufficient data. nr = none reported.

1/ Nonirrigated. 2/ Irrigated. 3/ Preliminary. 4/ May not add to 100 due to rounding. 5/ Conventional tillage with moldboard plow--any tillage system that includes the use of a moldboard plow and has less than 30 percent residue remaining after planting. 6/ Conventional tillage without moldboard plow--any tillage system that has less than 30 percent remaining residue and does not use a moldboard plow. 7/ Mulch-tillage--system that has 30 percent or greater remaining residue after planting and is not a no-till system. 8/ Ridge-tillage--system with the rows planted on ridges. 9/ No-tillage--no residue-incorporating tillage operations performed prior to planting; allows passes of nontillage implements, such as stalk choppers.

Appendix table 10--Tillage systems used in northern soybean production, 1992

Category	IL	IN	IA	MN	MO	NE	OH	Area
Planted acres (1,000) 1/	9,500	4,550	8,100	5,500	4,300	2,500	3,700	38,150
				Percent of acres 2/				
Tillage system:								
Conv/w mbd plow 3/	6	15	7	37	3	nr	18	12
Conv/wo mbd plow 4/	46	36	49	49	55	48	46	47
Mulch-till 5/	29	25	34	9	30	44	14	26
Ridge-till 6/	nr	id	1	1	nr	3	nr	1
No-till 7/	19	24	10	3	12	5	21	14
				Percent of soil surface covered				
Residue remaining after planting:								
Conv/w mbd plow	2	2	2	3	2	nr	2	2
Conv/wo mbd plow	18	19	18	12	16	17	14	16
Mulch-till	40	41	39	39	39	38	38	40
Ridge-till	nr	id	54	45	nr	43	nr	48
No-till	70	72	67	57	70	65	65	68
Average	33	35	30	13	29	29	26	28
					Number			
Hours per acre:								
Conv/w mbd plow	.6	.5	.6	.6	.8	nr	.6	.6
Conv/wo mbd plow	.4	.4	.4	.4	.5	.4	.5	.4
Mulch-till	.3	.3	.3	.4	.3	.3	.4	.3
Ridge-till	nr	id	.2	.2	nr	.2	nr	.2
No-till	.1	.1	.1	.1	.1	.1	.1	.1
Average	.4	.3	.3	.4	.4	.3	.4	.4
Times over field:								
Conv/w mbd plow	4.4	3.5	4.0	4.0	4.0	nr	3.5	3.9
Conv/wo mbd plow	4.0	3.5	3.6	3.8	3.9	3.2	3.6	3.7
Mulch-till	2.9	2.8	2.7	3.1	2.8	2.6	3.0	2.8
Ridge-till	nr	id	1.8	1.8	nr	1.5	nr	1.6
No-till	1.0	1.0	1.0	1.0	1.0	1.3	1.0	1.0
Average	3.1	2.7	3.0	3.7	3.2	2.8	2.9	3.1

id = Insufficient data. nr = None reported.

1/ Preliminary. 2/ May not add to 100 due to rounding. 3/ Conventional tillage with moldboard plow--any tillage system that includes the use of a moldboard plow and has less than 30 percent residue remaining after planting. 4/ Conventional tillage without moldboard plow--any tillage system that has less than 30 percent remaining residue and does not use a moldboard plow. 5/ Mulch-tillage--system that has 30 percent or greater remaining residue after planting and is not a no-till system. 6/ Ridge-tillage--system with the rows planted on ridges. 7/ No-tillage--no residue-incorporating tillage operations performed prior to planting; allows passes of nontillage implements, such as stalk choppers.

Appendix table 11--Tillage systems used in southern soybean production, 1992

Category	AR	GA	KY	LA	MS	NC	TN	Area
Planted acres (1,000) 1/	3,200	650	1,180	1,200	1,850	1,400	1,000	10,480
				Percent of acres 2/				
Tillage system:								
Conv/w mbd plow 3/	id	8	5	nr	nr	12	1	3
Conv/wo mbd plow 4/	92	60	42	85	85	63	62	76
Mulch-till 5/	4	24	9	11	9	6	4	8
No-till 6/	3	[illegible]	44	5	6	19	34	14
Residue remaining after planting:				Percent of soil surface covered				
Conv/w mbd plow	id	2	1	nr	nr	1	id	1
Conv/wo mbd plow	6	16	12	[illegible]	8	11	10	8
Mulch-till	51	41	38	37	42	43	42	42
No-till	59	75	60	59	68	70	61	63
Average	9	25	35	13	15	23	28	18
				Number				
Hours per acre:								
Conv/w mbd plow	id	.7	1.1	nr	nr	1.6	id	1.3
Conv/wo mbd plow	.4	.6	.5	.5	.5	.7	.5	.5
Mulch-till	.2	.3	.3	.3	.3	.4	.3	.3
No-till	.1	.2	.2	.1	.1	.2	.1	.2
Average	.4	.5	.4	.4	.4	.7	.4	.5
Times over field:								
Conv/w mbd plow	id	4.4	4.3	nr	nr	4.5	id	4.5
Conv/wo mbd plow	5.1	3.5	3.6	5.0	5.0	3.7	4.2	4.7
Mulch-till	1.7	2.5	2.4	2.8	2.9	2.3	2.3	2.4
No-till	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Average	4.8	3.1	2.4	4.6	4.6	3.2	3.0	4.0

id = Insufficient data. nr = None reported.

1/ Preliminary. 2/ May not add to 100 due to rounding. 3/ Conventional tillage with moldboard plow--any tillage system that includes the use of a moldboard plow and has less than 30 percent residue remaining after planting. 4/ Conventional tillage without moldboard plow--any tillage system that has less than 30 percent remaining residue and does not use a moldboard plow. 5/ Mulch-tillage--system that has 30 percent or greater remaining residue after planting and is not a no-till system. 6/ No-tillage--no residue-incorporating tillage operations performed prior to planting; allows passes of nontillage implements, such as stalk choppers.

Appendix table 12--Tillage systems used in spring and durum wheat production, 1992

Category	Spring wheat					Durum wheat
	[redacted]	MT	ND	SD	Area	ND
Planted acres (1,000) 1/	2800	2650	9200	2700	17350	2200
	Percent of acres 2/					
Tillage system:						
Conv/w mbd plow 3/	24	nr	6	8	8	7
Conv/wo mbd plow 4/	70	75	58	44	61	55
Mulch-till 5/	5	23	28	36	25	35
No-till 6/	id	id	8	12	6	3
Residue remaining after planting:	Percent of soil surface covered					
Conv/w mbd plow	3	nr	2	3	3	3
Conv/wo mbd plow	13	14	16	19	15	16
Mulch-till	43	37	42	39	41	42
No-till	id	id	53	51	53	68
Average	12	20	25	29	23	26
	Number					
Hours per acre:						
Conv/w mbd plow	.5	nr	.3	.3	.4	.3
Conv/wo mbd plow	.4	.3	.3	.2	.3	.3
Mulch-till	.3	.2	.2	.2	.2	.2
No-till	id	id	.1	.1	.1	.1
Average	.4	.3	.3	.2	.2	.3
Times over field:						
Conv/w mbd plow	3.9	nr	2.9	2.5	3.3	3.2
Conv/wo mbd plow	3.8	5.0	3.7	3.0	3.9	4.5
Mulch-till	3.0	3.1	2.4	2.0	2.4	2.5
No-till	id	id	1.1	1.0	1.1	1.0
Average	3.7	4.5	3.1	2.4	3.3	3.6

id = Insufficient data.

1/ Preliminary. 2/ May not add to 100 due to rounding. 3/ Conventional tillage with moldboard plow--any tillage system that includes the use of a moldboard plow and has less than 30 percent residue remaining after planting. 4/ Conventional tillage without moldboard plow--any tillage system that has less than 30 percent remaining residue and does not use [redacted] moldboard plow. 5/ Mulch-tillage--system that has 30 percent or greater remaining residue after planting and is not a no-till system. 6/ No-tillage--no residue-incorporating tillage operations performed prior to planting, allows passes of nontillage implements, such [redacted] stalk choppers.

Appendix table 13--Tillage systems used in cotton production, 1992

Category	AZ	AR	CA	LA	MS	TX	Area
Planted acres (1,000) 1/	320	980	1000	900	1350	5650	10200
	Percent of acres 2/						
Tillage system:							
Conv/w mbd plow 3/	47	nr	1	1	nr	18	12
Conv/wo mbd plow 4/	52	100	98	99	99	82	88
Mulch-till 5/	id	nr	id	nr	nr	id	id
No-till 6/	nr	nr	nr	nr	id	nr	id
Residue remaining after planting:	Percent of soil surface covered						
Conv/w mbd plow	0	nr	0	0	nr	0	0
Conv/wo mbd plow	1	1	1	2	2	4	3
Mulch-till	id	nr	id	nr	nr	id	id
No-till	nr	nr	nr	nr	id	nr	id
Average	2	1	2	2	2	4	3
	Number						
Hours per acre:							
Conv/w mbd plow	.9	nr	1.7	2.0	nr	.8	.8
Conv/wo mbd plow	1.1	.6	1.0	.6	.7	.6	.7
Mulch-till	id	nr	id	nr	nr	id	id
No-till	nr	nr	nr	nr	id	nr	id
Average	1.0	.6	1.0	.6	.7	.6	.7
Times over field:							
Conv/w mbd plow	6.3	nr	7.5	6.0	nr	6.3	6.3
Conv/wo mbd plow	5.9	6.1	7.2	6.0	6.3	5.4	5.9
Mulch-till	id	nr	id	nr	nr	id	id
No-till	nr	nr	nr	nr	id	nr	id
Average	6.0	6.1	7.2	6.0	6.3	5.6	5.9

id = Insufficient data. nr = None reported.

1/ Preliminary. 2/ May not add to 100 due to rounding. 3/ Conventional tillage with moldboard plow--any tillage system that includes the use of a moldboard plow and has less than 30 percent residue remaining after planting. 4/ Conventional tillage without moldboard plow--any tillage system that has less than 30 percent remaining residue and does not [redacted] a moldboard plow. 5/ Mulch-tillage--system that has 30 percent or greater remaining residue after planting and is not a no-till system. 6/ No-tillage--no residue-incorporating tillage operations performed prior to planting, allows passes of nontillage implements, such as stalk choppers.

Appendix table 14--Tillage systems used in rice production, 1992

Category	AR	LA	Area
Planted acres (1,000) 1/	1,350	600	1,950
	Percent of acres 2/		
Tillage system:			
Conv/w mbd plow 3/	nr	nr	nr
Conv/wo mbd plow 4/	96	92	95
Mulch-till 5/	4	5	4
No-till 6/	nr	3	1
Residue remaining after planting:	Percent of soil surface covered		
Conv/w mbd plow	nr	nr	nr
Conv/wo mbd plow	4	1	3
Mulch-till	45	45	45
No-till	nr	57	57
Average	5	5	5
	Number		
Hours per acre:			
Conv/w mbd plow	nr	nr	nr
Conv/wo mbd plow	.5	.4	.5
Mulch-till	.2	.2	.2
No-till	nr	0.0	0.0
Average	.5	.4	.5
Times over field:			
Conv/w mbd plow	nr	nr	nr
Conv/wo mbd plow	5.3	3.9	4.9
Mulch-till	2.6	2.5	2.5
No-till	nr	0.2	0.2
Average	5.2	5.7	4.7

id = Insufficient data.

1/ Preliminary. 2/ May not add to 100 due to rounding. 3/ Conventional tillage with moldboard plow--any tillage system that includes the use of a moldboard plow and has less than 30 percent residue remaining after planting. 4/ Conventional tillage without moldboard plow--any tillage system that has less than 30 percent remaining residue and does not use a moldboard plow. 5/ Mulch-tillage--system that has 30 percent or greater remaining residue after planting and is not a no-till system. 6/ No-tillage--no residue-incorporating tillage operations performed prior to planting; allows passes of nontillage implements, such as stalk choppers.

Appendix table 14--Tillage systems used in rice production, 1992

Category	AR	LA	Area
Planted acres (1,000) 1/	1,350	600	1,950
	Percent of acres 2/		
Tillage system:			
Conv/w mbd plow 3/	nr	nr	nr
Conv/wo mbd plow 4/	96	92	95
Mulch-till 5/	4	5	4
No-till 6/	nr	3	1
Residue remaining after planting:	Percent of soil surface covered		
Conv/w mbd plow	nr	nr	nr
Conv/wo mbd plow	4	1	3
Mulch-till	45	45	45
No-till	nr	57	57
Average	5	5	5
	Number		
Hours per acre:			
Conv/w mbd plow	nr	nr	nr
Conv/wo mbd plow	.5	.4	.5
Mulch-till	.2	.2	.2
No-till	nr	0.0	0.0
Average	.5	.4	.5
Times over field:			
Conv/w mbd plow	nr	nr	nr
Conv/wo mbd plow	5.3	3.9	4.9
Mulch-till	2.6	2.5	2.5
No-till	nr	0.2	0.2
Average	5.2	5.7	4.7

id = Insufficient data.

1/ Preliminary. 2/ May not add to 100 due to rounding. 3/ Conventional tillage with moldboard plow--any tillage system that includes the use of a moldboard plow and has less than 30 percent residue remaining after planting. 4/ Conventional tillage without moldboard plow--any tillage system that has less than 30 percent remaining residue and does not use a moldboard plow. 5/ Mulch-tillage--system that has 30 percent or greater remaining residue after planting and is not a no-till system. 6/ No-tillage--no residue-incorporating tillage operations performed prior to planting; allows passes of nontillage implements, such as stalk choppers.

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